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Model for a Specific Decision Support System for Crew Requirement Planning in Ship Management

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Abstract

Ship management has to face volatile business conditions, escalating volumes of information, and increasing complexity of company processes. Especially crewing, as one main task with significant fixed operating costs, imposes increasing demands for decision support. This contribution proposes a specific decision support system (SDSS) model for crew requirement planning for medium and large-sized shipping companies on an online analytical processing (OLAP) related structure. It gives a brief investigation of core information needs and associated basic data types before the model is developed. Additionally the underlying mathematical scheme and an appropriate user interface are depicted.

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Keywords: decision support systems; information management; ship management; crew requirement planning

1. Introduction and structure

The shipping business operates in a complex business environment. This is due to the current economic situation, which is characterized by significant competitive pressure and rising operational costs. Other challenges include the increasing number of updates in international maritime rules and regulations resulting in escalating volumes of information and increasing complexity of company processes (John 2013).

This leads to enhanced requirements within the planning processes and in consequence shipping managers show rising demand for effective and efficient decision support (systems).

Especially crewing, as one main task of ship management with a significant share of fixed operating costs, covers a wide variety of activities (see depiction 1) and is embedded in a complex network of relationships between multiple parties, e.g. ship agents, charterers or crewing agencies.

Key tasks of planning include crew requirement planning as a starting point for the operative crew scheduling and the strategic career planning, apart from the necessary administrative tasks.

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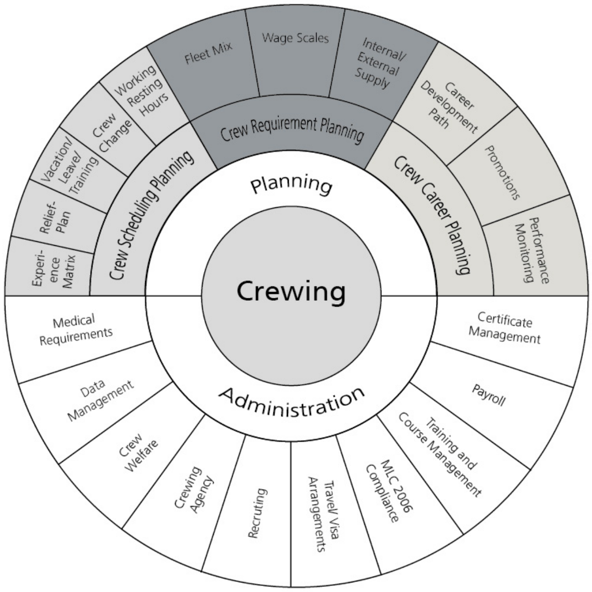

Fig. 1 Main Task of Crewing (own elaboration).

In shipping crew requirement planning bundles numerous planning tasks coping with the challenge of resource/crew allocation, according to a distinct goal, mostly budget limitations and under various constraints, e.g. Maritime Labour Convention (MLC 2006) or Standards of Training, Qualification and Watchkeeping (STCW) requirements.

In general, the goal of crew requirement planning is to adjust the personnel capacity to the long, middle as well as short-term personnel demand (Wöhe & Döhring 2005). More precisely, the personnel demand identifies the actual and future target number of employees strictly necessary to attain the company's goals. Latter are specified in qualitative, quantitative and time related aspects. Simultaneously, the planning process exposes shortfalls or surplus of personnel demand (Berthel & Becker 2003).

For shipping companies this calculation represents a major challenge. Especially, when they operate their own ships with a mix of permanent and non-permanent contracts and provide crew management on behalf of clients for whole ships or designated positions with distinct budget respective wage scale requirements.

Two detailed studies of the market of current software applications for shipping companies conducted in 2011 and 2013 show that in practice none of the common proprietary systems provides a mature solution covering the detected needs (John 2013; Jahn, John & Münsterberg 2012). At this moment no suitable approach or for enhanced crew requirement planning for shipping companies could be identified by the authors in the existing literature.

Decision Support Systems (DSS) are used to support deciders in the field of planning and controlling processes. The first consideration in modeling a DSS touches the information needs and the information demand of the decider as well as the provision of an adequate information basis (Fink 2000).

Therefore in the following chapter the key information needs of deciders involved in crew requirement planning will be pointed out. Furthermore the three relevant planning dimensions in ship management are depicted, followed by the identification of relevant crew requirement planning data.

The sole provision of information in a complex and semi-structured decision environment is not sufficient. For planning, decision, and control processes deciders need an access to models and methods additionally (Stallknecht & Hasenkamp 2005). Decision support in the narrow sense refers to a distinct decision or a class of decisions, where the support is based on formal models of different complexity (Krcmar 1990). SDSS go beyond sole data support, by providing model-based analyses of alternatives and assist the evaluation of action strategies (Gluchowski, Gabriel & Chamoni 1997).

Taking these considerations into account, in the third chapter a SDSS model for crew requirement planning in ship management, with the referring mathematical model, is constructed based on a four dimensional OLAP structure. In addition the paper presents a proposal for an user interface. In the final chapter possible further optimization opportunities related to other planning tasks in crewing and ship management will be pointed out.

2. Key information needs and data requirements of crew requirement planning

The main information need in crew requirement planning is the actual respective future shortfall or surplus of personnel demand. In order to determine the gap between personnel demand and supply following information must be provided:

Regarding the calculation of existing staff:

The quantity of seafarers, differentiated by qualifications (e.g. "instant rank"), which offers the pool of staff today and in future.

Regarding the calculation of personnel demand:

The quantity of seafarers, differentiated by qualifications (e.g. "instant rank"), demanded today and in the future in order to occupy specific positions on different ship types and groups:

- compliant to national and international regulations;
- as stated by budget limitations for single ships or ship groups and
- according to requested crew specifications by charter parties.

In this contribution the personnel demand will be calculated according to the following basic scheme: the present-day respective the future fleet mix plus the budget limitations represent the independent variable, while the personnel demand is considered as dependent variable. Further data could be optionally incorporated as parameter or intervening variables for certain needs.

Three dimensions are relevant for both calculations: ship, personnel and position. In all three dimensions existing physical objects are defined as the lowest level of granularity: ships in the ship dimension, seafarers in the personnel dimension and positions in the position dimension. They represent the original data. In Fig. 2 all original data with the corresponding attributes are shown. The possible aggregation of original data is demonstrated by the rising number of cubes.

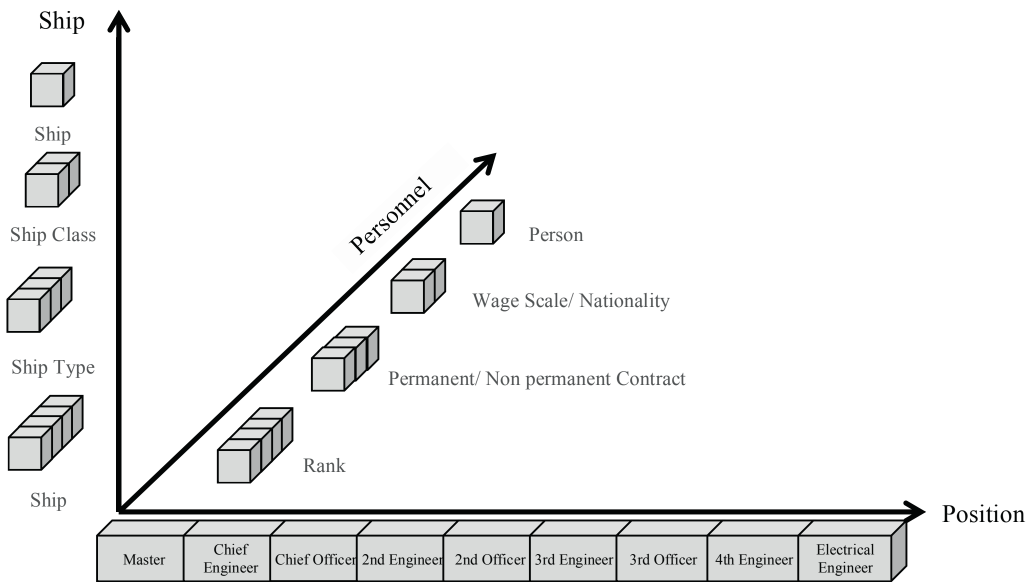

Fig. 2 Three dimensions for personnel demand and supply calculation.

In the ship dimension the specific vessel is defined by a ship identification label (e.g. ship name or IMO number), all occurring ship classes [SC] (e.g. Panamax, Post-Panamax, Super-Post-Panamax), the corresponding ship types [ST] (e.g. container, bulker, tanker, etc.) and as in most shipping companies an organizational ship group [SG].

In the personnel dimension a seafarer is defined by the personnel identification label (e.g. his/her name), his wage scale [WS], depending on instant rank and nationality as well as the contract type (permanent or non-permanent). The rank is a temporary attribute, granted by the shipping company through the allocation of a seafarer to a certain ship position.

The position dimension describes all positions [POS], valid for all possible ship types, to be filled with officers of the deck and engine department. Every position on a specific vessel must be assigned only once. Though, the safe manning certificate, provided by flag state, rules, which positions have to be manned.

In this paper the focus lies on officer positions, as for ratings the situation is less complex and could be handled simultaneous. Based on these considerations the basic data support, illustrated in Table 1, is necessary.

Table 1 Overview of basic data types.

Data type 1	**Attribute**					
Ship	Ship ID	Ship Class	Ship Type	Ship Group		
Example	*MV Blue*	*Supramax*	*Bulker*	*Ship Group 1*		
Data type 2	**Attribute**					
Personnel	Name ID	Nation/Wage Scale	(non) Permanent Contract	Rank	Ship Class	Ship Type
Example	*Bo Heart*	*USA/WS 12*	*permanent contract*	*2nd Officer*	*Panamax*	*Container*
Data type 3	**Attribute**					
Position	Position					
Example	*Master*					
Data type 4	**Attribute**					
Period	Year	Quarter	Month	Day		
Example	*2012*	*2nd Quarter*	*November*	*21*		

3. Construction of a SDSS Modell

For the construction of the SDSS model for crew requirement planning the OLAP method is used. OLAP provides fast and interactive query and analysis of multi-dimensional data marts (Codd, Codd & Sally 1993). OLAP was chosen, because it is able to provide data, calculations and information on any aggregation level over the multiple dimensions of the crew requirement problem. This is user-oriented, because it allows ship managers to navigate through the data calculation results tailored to the information needs given by the current problem. Furthermore results can be presented and visualized individually according to users‘ requirements. OLAP is data mart oriented, this means it works on pre-selected and pre-aggregated data instead of transaction level data (Lusti 2002).

The first step is to transfer all data required in a multi-dimensional OLAP cube. Starting from the three crewing dimensions (ship, position and personnel) presented in Fig. 2 and adding time as the fourth planning dimension in ship management. Fig. 3 shows the resulting crew requirement-planning cube (CRP-Cube).

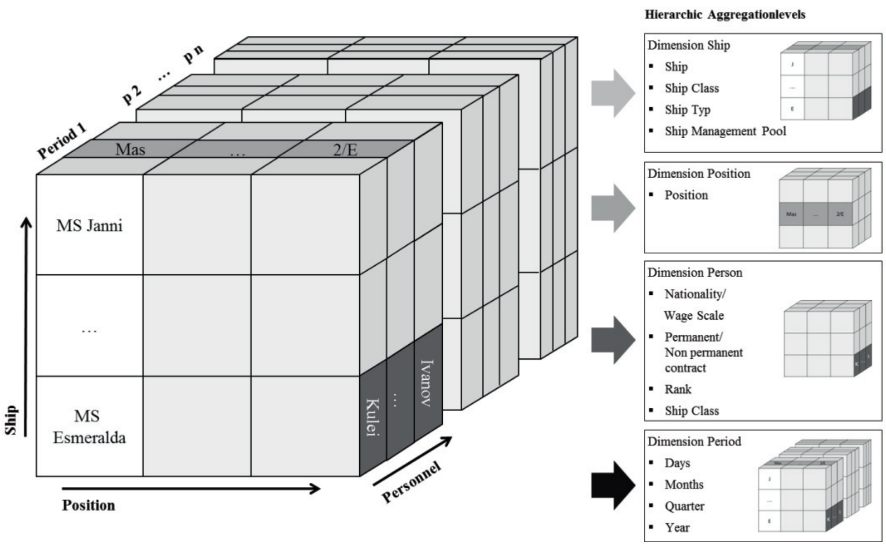

Fig. 3 CRP-cube.

All four dimensions of the cube can be further divided into their according aggregation levels (see previous section).
Finally the fourth dimension time could be divided into different planning horizons given by the actual decision problem.

3.1. Target vs. actual seagoing staff ('Gap = Supply – Demand')

Major intention of the crew requirement planning adjust the personnel capacity to the long, middle as well as short-term personnel demand and thus balance the actual inventory of seagoing resources with the targeted (theoretical) amount of staff needed. Using a mathematical expression, we try to minimize the gap (G) between the supply (S) of seagoing staff – given by the actual seafarers on the ship manager's payroll – and the demand (D) for seagoing staff – created by the ships under management.

$$G_{pos;ws;sc;sg}^{\text{year n}} = S_{pos;ws;sc;sg}^{\text{year n}} - D_{pos;ws;sc;sg}^{\text{year n}} \quad (1)$$

where

- G = gap between personnel supply and demand
- S = personnel supply
- D = personnel demand
- year n = time period of interest (in this case a full year)
- pos = position
- ws = wage scale/nationality
- sc = ship class
- sg = ship group.

The determination of supply and demand part of the equation will be described in the following, using the CRP-Cube structure described above.

3.2. Determining the current and projected staff base ('Supply')

For the determination and analysis of the actual staff base (supply) it is important to distinguish between various paid and unpaid activities a seafarer cumulates over an accounting period. Only paid activities (such as sea service, regular paid leave, sick leave, travel time, training time) should be accounted for in the supply base. Unpaid activities, such as welfare leave, should be excluded. Fig. 4 shows the CRP-Cube filled with exemplary personnel supply data.

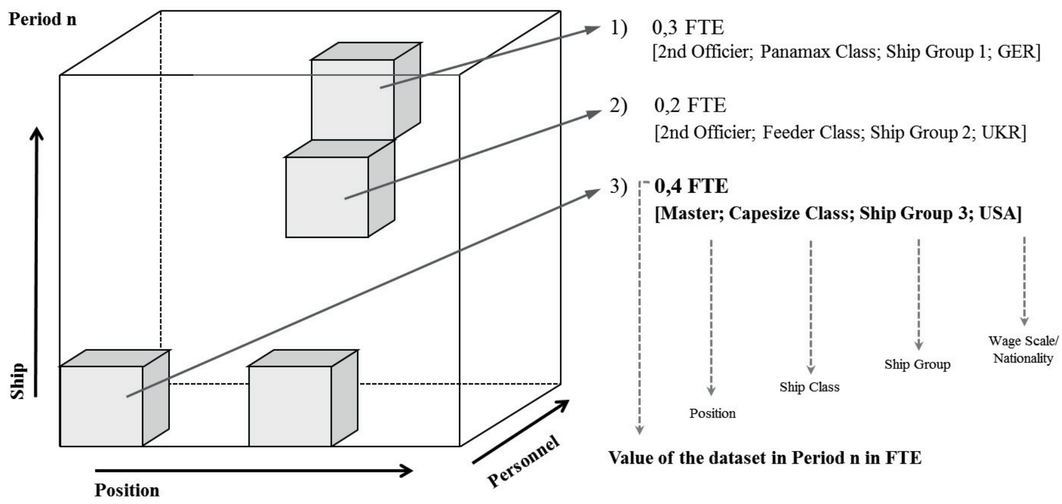

Fig. 4 CRP-Cube filled with exemplary supply data.

Seafarers paid active time (measured in full time equivalents FTE) is divided along the four dimensions and to the lowest aggregation level used in this example. For example 3) in figure 4 describes a data point in which a seafarer of USA nationality (and an according wage scale) has worked with 40% of a full time equivalent as a Master on a Capesize Class ship, in a ship management group called “Ship Group 3”. Consequently this seafarer contributes 0,4 FTE to the overall personnel supply.

Based on the OLAP structure the total actual staff (year 0) is calculated as an addition of all the values in the cubes elements. As a mathematical expression

$$S^{\text{year } 0} = \sum_{pos \in POS} \sum_{ws \in WS} \sum_{sc \in SC} \sum_{sg \in SG} S_{pos;ws;sc;sg}^{year\ 0} \tag{2}$$

where

- POS = set of all Positions
- WS = set of all Wage Scales
- SC = set of all Ship Classes
- SG = set of all Ship Groups.

Starting from the current staff base and again using the OLAP structure a projection of the future staff base is reasonable. For this purpose a number of supply projection factors is deposit in the cub’s structure. Using the exact same data structure ensures that for each data point of the actual staff base all supply projection factors have values assigned accordingly. The CRP-Cube visualization in Fig. 5 demonstrates the calculation logic for the supply projection.

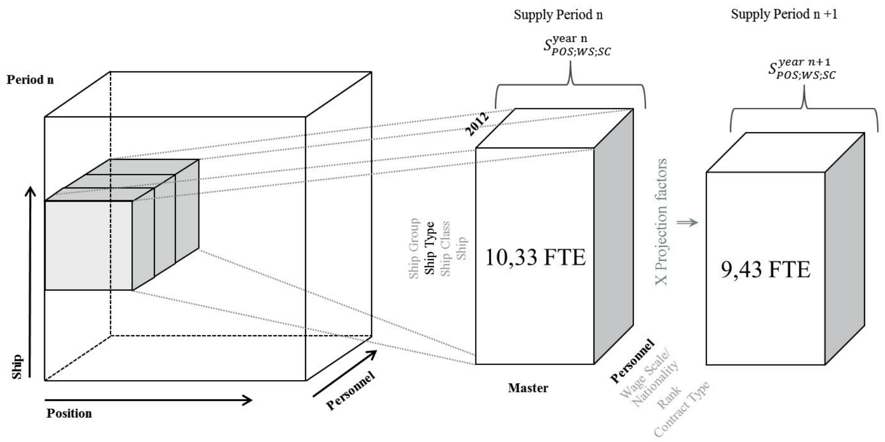

Fig. 5 Using the CRP-Cube for supply calculations.

Following, the most granular element of the cube filled with the supply data of the base year is selected. In the next step all according supply projection factors are summed up and have been multiplied with the base supply. To receive results for the total supply calculation results for all relevant cube elements are added up (e.g. to receive results for all masters). In the mathematical model the supply projection is described as

$$S^{\text{year n+1}} = \sum_{pos \in POS} \sum_{ws \in WS} \sum_{sc \in sc} \sum_{sg \in SG} S_{pos;ws;sc;sg}^{\text{year n}} \times SF_{pos;ws;sc;sg}^{\text{year n+1}} \tag{3}$$

with

$$SF_{pos;ws;sc;sg}^{\text{year n+1}} = 1 + \left(sf_{pos;ws;sc;sg}^{Ret;year\ n+1} + sf_{pos;ws;sc;sg}^{Res;year\ n+1} + sf_{pos;ws;sc;sg}^{Promout;year\ n+1} + sf_{pos;ws;sc;sg}^{EmplO;year\ n+1} + sf_{pos;ws;sc;sg}^{Promin;year\ n+1}\right)$$

where the following factors reduce the current supply base towards the next time period

- Retirement $sf_{pos;ws;sc;sg}^{Ret,year\ n}$
- Resignment $sf_{pos;ws;sc;sg}^{Res,year\ n}$
- Promotions out Rank $sf_{pos;ws;sc;sg}^{Promout,year\ n}$
- Miscellaneous $sf_{pos;ws;sc;sg}^{Misc,year\ n}$

and the following factor increases the current supply base towards the next time period

- Promotions in Rank $sf_{pos;ws;sc;sg}^{Promin;year\ n+1}$.

3.3. Determining the target amount of staff ('Demand')

The determination of the targeted amount of seafarers starts from the number of ships that need to be staffed. Due to ship class and type, safe-manning, budget, or charterers' requirements, it is possible to calculate how many positions per ship (or in a group of ships) are needed to run the fleet. To be able to staff the vessels continuously the ship manager has to take several off-board activities into account, which increase the total demand for seafarers. It should be noted that the relative importance of factors may vary between ship managing companies. To calculate the target demand of seafarers following addition factors are included:

- Paid leave (vacation) $df_{pos;ws;sc;sg}^{Leave;\text{year n}}$
- Sick leave $df_{\text{pos;ws;sc;sg}}^{\text{Sick;year n}}$
- Training $df_{pos;ws;sc;sg}^{Training;\text{year n}}$
- Travel $df_{pos;ws;sc;sg}^{Travel;\text{year n}}$
- Waiting $df_{pos;ws;sc;sg}^{Waiting;\text{year n}}$.

These factors act as percentage addition factors on the sea service time. Thus, the demand for seagoing personnel in period n is calculated as

$$D^{\text{year n}} = \sum_{pos\in POS} \sum_{ws\in WS} \sum_{sc\in SC} \sum_{sg\in SG} D^{\text{Basic year n}}_{pos;ws;sc;sg} \cdot DF^{\text{year n}}_{pos;ws;sc;sg} \quad (4)$$

with

$$DF^{year\ n}_{pos;ws;sc;sg} = 1 + \left(df^{Leave;\text{year n}}_{pos;ws;sc;sg} + df^{Sick;\text{year n}}_{pos;ws;sc;sg} + df^{Training;\text{year n}}_{pos;ws;sc;sg} + df^{Travel;\text{year n}}_{pos;ws;sc;sg} + df^{Waiting;\text{year n}}_{pos;ws;sc;sg}\right)$$

and

$$D^{\text{Basic year n}}_{pos;ws;sc;sg} = \sum_{v\in V} z^{\text{v; year n}}_{pos;ws;sc;sg}$$

while

- $z^{\text{v; year n}}_{\text{pos;ws;sc;sg}}$ = number of all positions of type pos on vessel v of ship class sc in ship group sg, that need to be staffed with a seafarer of wage scale ws in year n
- V = set of all vessels.

Calculation logic of the personnel demand is the same for every year. Again the CRP-cube is used to organize and store the demand addition factors and demand calculation results. This ensures that supply and demand data for every period is available in the same data structure and users can compare supply and demand (and the resulting gap), just-as-needed to provide automatically the specific information needs.

3.4. Proposal for a user interface

The OLAP structure of data and calculation support a convenient visualization. Fig. 6 shows an exemplary user interface with a parameter, a navigational and a result presentation section.

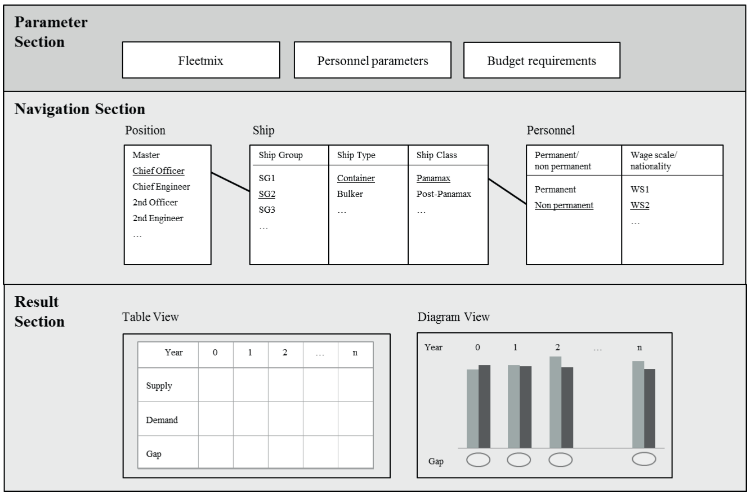

Fig. 6 Proposal for an user interface.

The user is able to select the desired aggregation level of information in the navigation section, which is organized according to the dimensions of the CRP-Cube. Based on the selection the appropriate information is selected from the CRP-Cube and can be displayed in a user defined way (e.g. diagrams or data tables) in the results section.

4. Conclusion and Outlook

Within this contribution key information needs for crew requirement planning purposes in ship management have been examined. Based on the demand planning related dimensions ship, personnel and position, basic data types have been derived. Following, a SDSS model has been proposed, which is capable to calculate the gap between personnel demand and supply of seafarers today and in the future taking several constraints and parameters into account. The functionality has been proven by implementation in a medium-size ship management company. Notwithstanding, the proposed SDSS model will be fully effective unless other personnel planning related areas like the challenging crew scheduling problem (John, Böttcher & Jahn 2013) or career planning have not been fully included in an integrated personnel planning system. Personnel demand planning penetrates other planning levels and should not be separated (Berthel 2003).

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