A state-time model to measure the Reconfigurability of Manufacturing Areas – Key to performance

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0 Motivation

Recent years showed a considerable shift in manufacturing success factors. Quality price, speed and flexibility are already standardized /8, 16, 18, 21/. The new challenge is reconfigurability – the ability of self-driven changes within organizations /3, 4, 5, 11, 17/. Regarding this new requirement for manufacturing enterprises it is essential that reconfigurability obviously can not be measured but it becomes more and more important /1, 3, 13/. Reconfigurability is the main characteristic of recent manufacturing approaches like Agile manufacturing /4, 6, 8, 9, 11/, Bionic / Biological Manufacturing Systems /20, 27/, Viable manufacturing systems /14, 23/, Autonomous and Distributed Manufacturing Systems /19/ or the Fractal Company /16, 17, 18/. Reconfigurable structures are able to organize and optimize themselves /12/. Self-organization and self-optimization are processes of change from one structural state to another /2/. Current approaches of measurement and evaluation of manufacturing areas focus on business processes /7, 9, 10, 13, 24/. The change in structure is not yet extensively investigated, especially with regard to the speed for changes. The measurement of reconfigurability bases on results of changes. A "high" or "low" reconfigurability can be measured by analyzing change processes and the prerequisites of reconfigurability can be pointed out.

1 The Model

Let MAN be a manufacturing unit.
Following notation and definitions are given:

t_p state (MAN) present state of MAN
t_d state (MAN) desired state of MAN

t_p, t_d, t ? T	t_p present time t_d desired time to achieve t_d state (MAN)
$P = U_{i=1...n}\ p_i$	p set of projects p_i to achieve t_d state (MAN)

These objects are depicted in Fig. 1.

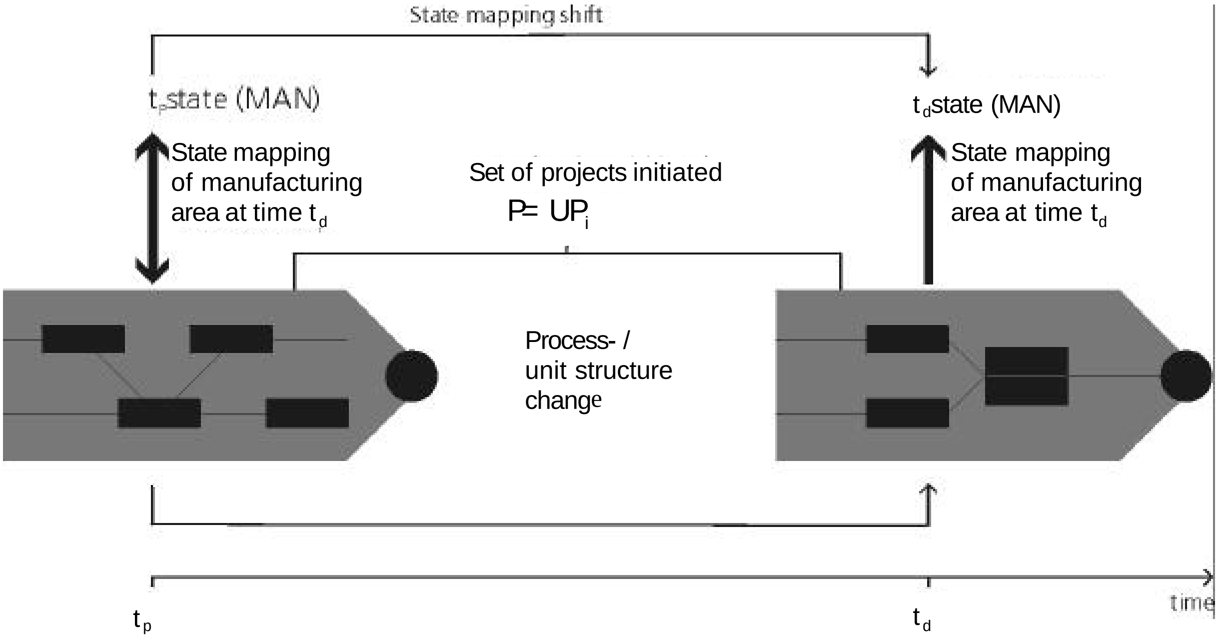


Fig. 1: State mapping shift during time period (t_P, t_d); Quantification of changes of manufacturing structure

Therefore, the ability to change is the principle of reconfigurability. The basic criteria to measure this ability are

?? time consumption /22/ and
?? structuring result /10, 25, 26/.

In order to measure the reconfigurability of process structures two steps are emphasized:

1) Mappings and Measurement of states

2) Evaluation of time / change relations

2 Mappings and measurement of states

To define the structural state of a manufacturing area detailed measurement criteria can be given. The criteria based on a model that is specially designed for autonomous decentralized units /12/. Instead of detailed descriptions of every task the manufacturing area can be regarded by states and mappings of states.
A manufacturing area can be modeled as

t state (MAN)? $(T_W(t), O_k(t), R_g(t), U_f(t))$

where T_w T set of tasks
w Index of all tasks to be regarded
O_k O set of objectives
k Index of objectives
R_g R set of resources, materials parts etc.
g Index of resources regarded
U_f U set of transformation units
f Index of transformation units regarded
t denotes the time t? T where T is the (ordered) time set ? R_o^+.

Any element of the sets introduced above can be assigned to a scale indicating ratios, multitudes and consumptions of units.

This model is now not to be detailed by tasks-resource assignments or similar relations. For reconfigurability, a purely observable oriented view has proven to be fruitful. In order to quantify results, the state view of the model can be given as follows:

Tab. 1 shows an example several defined components to describe states of a manufacturing area MAN.

I	Component	Dimension	Objectives / Resources / Constraints
1	Lead Time	Days	Objectives
2	Quality	%	Objectives
3	Budget	$ / Year	Resources
4	Personnel capacity	h / Month	Resources
5	Personnel flexibility	% / Year	Transformation unit
6	Machinery flexibility	% / Month	Transformation unit

Tab. 1: Example of state mapping in a manufacturing area state (MAN) using 6 components

3 Evaluation of time/change relations

Time measurement is introduced due to the requirement that reconfiguration in the manufacturing area must be possible faster than changes of external influences. Therefore, the speed of change is an important figure of success in manufacturing. Change processes that are fast indicate a high reconfigurability. By measuring and comparing the values it is helpful to compare between required time t_R for changes and available desired time t_D for changes. Changes should be neither too slow nor too fast. Changes that run too slow have their origin in a poor reconfigurability and rigid organizational structures. Changes that are possible too fast usually indicate costly redundancies.

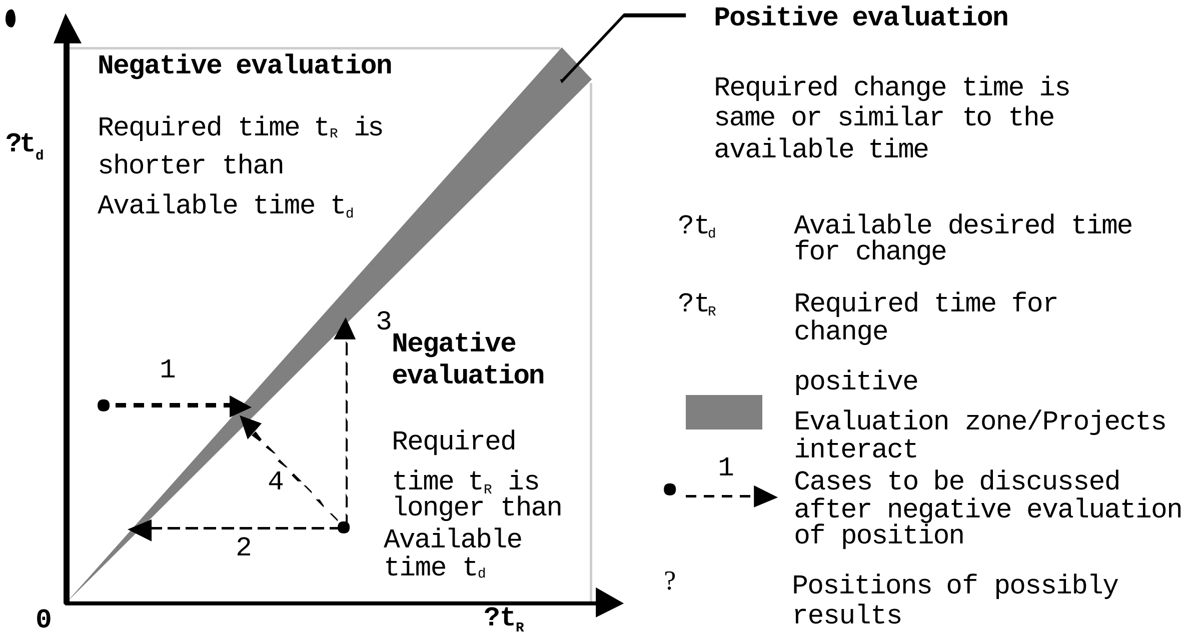


Fig.4: Tolerance logic/current monitoring of projects U_iP impact

State mappings can be given for past, present and desired states. Evaluations of desired developments concerning the manufacturing area MAN can be anticipated by initiation of structural changes. Questions like "does our manufacturing fulfill future requirements" can easily be answered using the method. Using the past, the present or the future focus however, the measurement result can be summarized.

Important monitoring positions:

Position 1

Expected time for change is shorter than the available time period. In this case, changes can be started and finished before time. The alternative is starting the projects later. This alternative should especially be chosen if project capacities are required elsewhere in process. Case 1 indicates oversized reconfigurability. Therefore redundancies should be taken out of the set up of the manufacturing areas.

Position 2

Expected time consumption for change is longer than available time; acceleration of the change.
In this case there are several alternatives, for example better technical support, introduction of more effective methods or increasing the qualification of the staff. All actions should point to increase reconfigurability.

Position 3

Expected time consumption is longer than the available time; extension of available time period.
This option is the most frequent case but dangerous. Especially in turbulent environments any extension of time for necessary changes result in diminished success. Nevertheless, there can be special situations where the extension of available time for change be a strategic advantage.

Position 4

Expected time consumption for change is longer than available time t_A; acceleration of change plus extension of available time period - superposition of case 2 and case 3. To increase or decrease reconfigurability a number of catalyzing actions can be given respectively (table 3). Tables like this can be used to control the reconfigurability in cases of an in adequate speed of change processes.

Projects to improve reconfigurability	Selection and training of team leaders	Staff selection and training	Technical concept	Tooling concept	New comminication oriented layout	Information of all	New floor in the manufacturing area	New electrical facilities	Machine layout	Technical qualification	Initiation of Continous Improvement Processes	Design of new information and communication boards
Goal commitments												?
Increase of outside-orientation of goals						?						
Identification of core processes		?		?								
Integration of tasks for flexibility	?											
Decentralization	?											?
Communication oriented factory layout			?		?		?		?		?	
Self-controlling										?	?	?
Increase of technical flexibility							?	?	?	?		

Tab. 3: Projects and parallel actions taken to change abilities of reconfiguration and speed up changes (Position 4)

4 Case Study

The method was applied to the manufacturing area of company producing electrical devices. Unsatisfying lead times and unability of on-time delivery as well as unsuccessful reengineering projects showed insufficient reconfigurability in the manufacturing areas. This insufficiency has been verified by comparison of past, present and forecasted state mappings of the structure. Several manufacturing units A – D were looked at. Figure 6 represents the mapping with satisfying results in the assembly unit B. On the other hand it is obvious that in the other units A, C and D still show differences between the intended values and the actual achieved values. Therefore actions had to be taken to accelerate change processes within these units. To increase reconfigurability a list of project steps was emphasized.

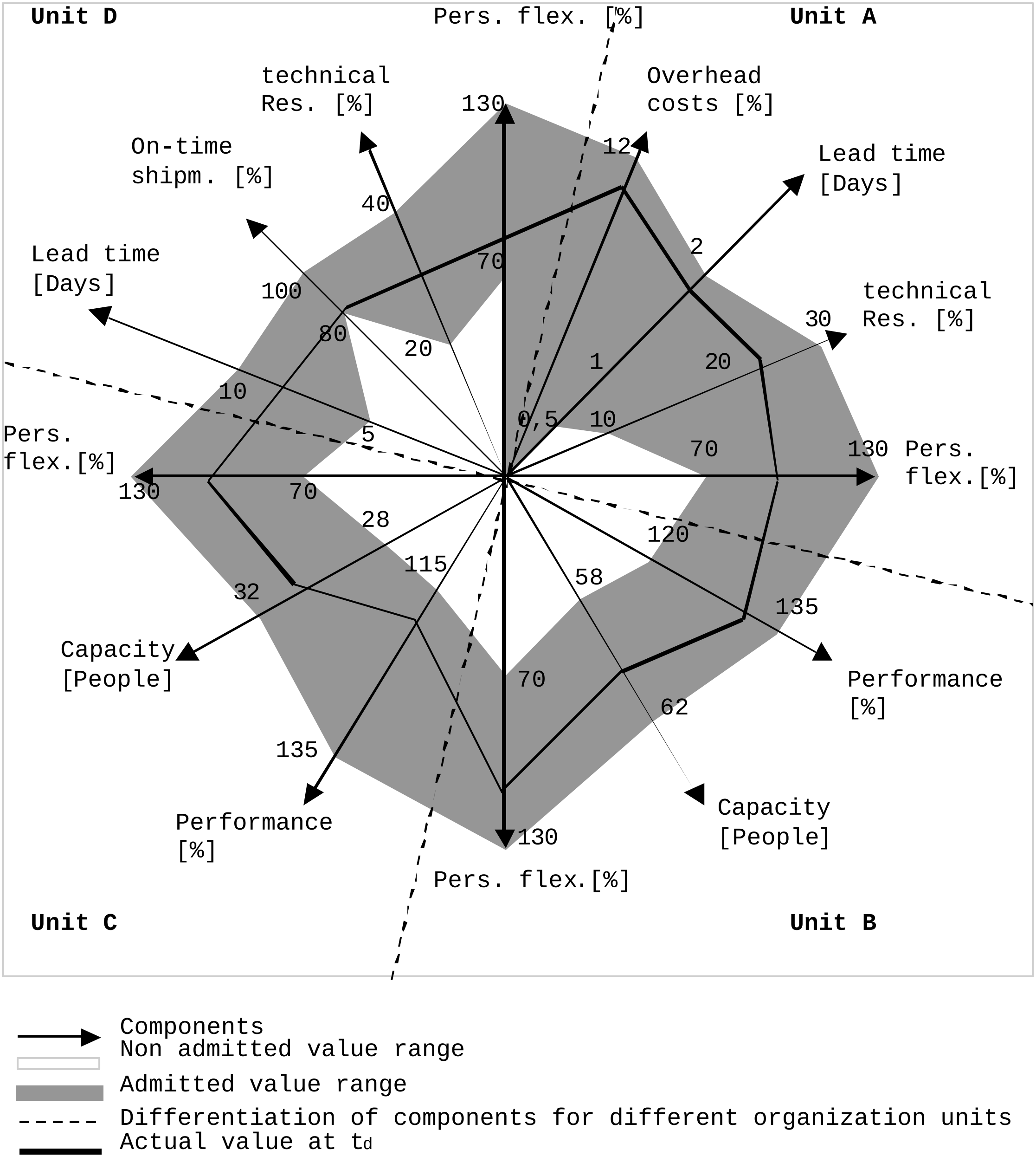


Fig. 6: State mappings of manufacturing area after change (at time (t_d))

In this example the desired time t_d for change was limited to 40 weeks. Forecasts for values mapping future states $t_?$ state (MAN) at time $t_?$ showed t_E?40 week by far.
Basis where mappings of t state (MAN) and it’s trajectories for each dimension.
But t_E?40 would mean considerable disadvantages on the market resulting in loosing market shares to competitors.(Case 2)
Project efforts had to be taken into account as well as deep cuts into the organisation.

As splendid result the reconfiguration was completed after 38 weeks. Therefore, the organization verified their reconfigurability due to the implementation of action catalogues. Selection of concret actions enabled the company to do this important restructuring process, that had failed several times before.

t_0 state MAN → **t_d state MAN**

Projects and actions

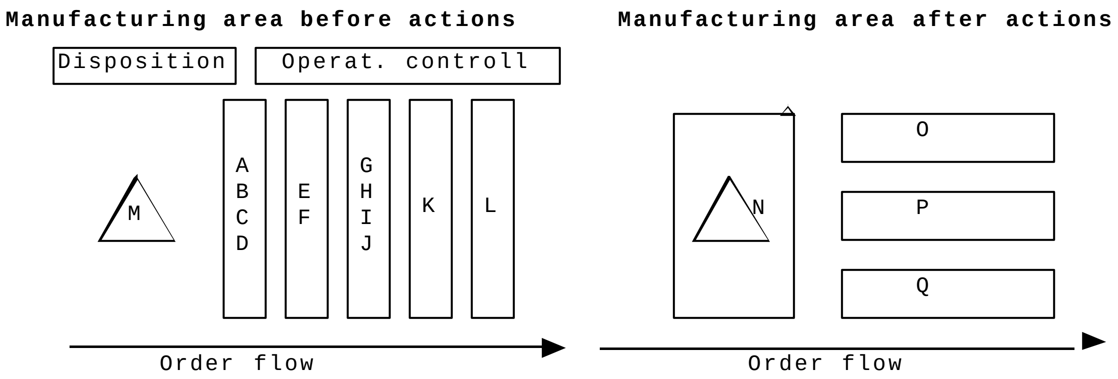
- Selection and training of team leaders
- Staff selection and training
- Technical concept
- Tooling concept
- New communication oriented layout
- Information of all participants
- New floor
- New electrical facilities
- Machine layout
- Technical qualification
- Initiation of Continous Improvement

Processes

- Design of new information and communication boards

t_0? t_d 38 weeks

Fig. 7: State mapping shift of manufacturing area.



A	TC 260		M	Materials of stock
B	Sawing		N	Material center with raw mat. stock and cutting
C	Big presses			
D	Cutting			
E	Front panel manuf.		O	Manufacturing cust. anonym. parts
F	NC-stamping			
G	Stamping		P	Manufacturing cust. orient. systems
H	Mechanics			
I	Bending		Q	Manufacturing cust. oriented. parts
J	Grinding			
K	Profile manufacturing			
L	Pre-assembly			

Fig. 8: Comparising of manufacturing area structure before and after reconfiguration t_0 state (MAN) and t_1 state (MAN)

5 Conclusions

Reconfigurability is an important success factor in manufacturing. It is essential that manufacturing structures can be changed appropriate

and within adequate time. Selforganized and autonomous units do not use scheduling and PPC in the classical sense. As soon as objectives are set (by customers or competitors) a manufacturing area is obliged to fulfillment.
In this situation control parameters of structure mappings and forecasted time consumption for parameter shift of mapping can be used in order to determine necessary projects or recommended actions to be chosen.

This paper points out a model that supports change management by measuring the reconfigurability of manufacturing areas with the focus on time consumption for reconfiguration. Time parameters and results of changes are essential criteria. Furthermore the model enables to control the reconfigurability by well defined implementation projects and actions to increase or decrease reconfigurability respectively.

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