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Defining Production Process as a Technical System – SIPOC/9W

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Abstract There is a need for the improvement of production processes. When systematic creativity as TRIZ is used for process innovation, it can be tricky for non-experienced TRIZ users. Because TRIZ principles are aiming at evolution patterns of technical systems, it can be helpful to describe the production system or production process in technical system terminology. This paper aims to the determination of elements of the technical system in production processes. Laws of technical system evolution are reviewed and applied to the process improvement point of view. Results of the paper can be used as a starting point for using TRIZ principles for process improvement or for designing a new method for the use of TRIZ by inexperienced users.

Keywords production process, technical system, process improvement, process innovation, 9 windows, SIPOC, TRIZ

1. INTRODUCTION

There is a continuous need for improvement of production processes. To achieve significant changes, innovation of the production system is crucial. One of the best approaches how to innovate the technical system is TRIZ. [1–4]

Many authors tried to use the TRIZ itself or with other tools to improve production processes [5]. TRIZ is very powerful, but it can be tricky to use it effectively without experience and good knowledge of TRIZ thinking. Unfortunately, it can take a long time To learn TRIZ principles well. [6–9] There should be a way how to apply a TRIZ easily, but with good results of improving yields [10]. To find a way how to approach to the process innovation by TRIZ principles easily. There is a need for a deeper understanding of a production system or production process represented by a technical system. A Description of the production process as a technical system should be examined.

This paper aims to describe the production system as a technical system in terms of TRIZ methodology, with a goal to find a way how to apply TRIZ principles for process innovation more easily. Laws of the evolution of technical systems are applied in the process improvement context. Also, several ways of using the TRIZ tools and principles in the process context are proposed.

2. TECHNICAL SYSTEM BY TRIZ

The technical system consists of several elements. The functionality of the technical system exceeds the functionality from a simple sum of elements functionalities. Technical systems exist to provide positive functions. The main parameters of the technical systems are: functionality, completeness, organization, and systematic quality. [11] The relationship between these parameters is shown in equation (1) below

$$F + S + O = Q \tag{1}$$

where F is a function of the system; S is system structure; O is an organization of the system; Q is quality or system effect. [11]

The evolution of technical systems is following several laws. Overview of laws of evolution of technicals systems is listed below:

- Law of completeness of a technical system
- Law of an abundance of a technical system
- Law of coordination of a technical system
- Law of energy conductivity in a system
  - Law of the existence of links between parts of a technical system
- Law of consistency of rhythm of activities of a technical system
- Law of transition to supersystem
  - Mono-bi-poly
- Law of increasing of the degree of the ideality of a technical system
- Law of irregularity of system's part evolution
- Law of increasing of the degree of systems dynamics
  - Law of transition of a system from macro- to microlevel
    - Changes of a scale
    - Changes of linking
    - Transition to more complex and energy-saturated forms
  - Law of increase of substance-field interactions
  - Law of increase of information saturation
    - Decreasing the degree of human involvement
- Law of increase of the degree of fragmentation
- Law of increasing the degree of control over a system

[12, 13]

Representation of technical system essential elements by the law of completeness can be seen in figure (Fig. 1). Where engine represents energy source, transmission is an energy converter, and the working unit can be represented as a tool. Sometimes an object can also be considered.

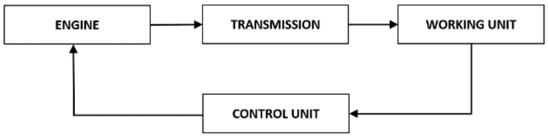

Fig. 1: Essential parts of a technical system [12, 14]

For the completeness of a system, CTS (Complete Technical System) method can be used. The tool performs the function on the object. The energy makes it possible for the tool to do work. The transmission delivers the energy to the tool. The control adjusts and improves the function (active) or enables the function (passive). The object is the thing that changes as a result of the function. [15]

Tool for understanding relationships between the technical system and its sub and super system evolution is called Multi-screen diagram also known as 9 windows, or system operator. It places the system in the middle of nine windows, where columns represent past, current, and future systems, and rows are system, supersystem, and sub-system. [15]

Super-system	TS	TS	TS
System	TS	**TS**	TS
Sub-system	TS	TS	TS
	past	*now*	*future*

Fig. 2: Multi-screen diagram known as 9 windows (9W)

3. PRODUCTION PROCESS DESCRIBED AS A TECHNICAL SYSTEM

For a description of a production process as a technical system, the function, structure, organization, and effect should be determined. The effect, or quality, is clearly the outcome of the process. It can be a product or service. Functionality can be represented as operations or tasks that have to be done to change process input to final output. The continuity of process steps can represent the structure. The organization is then represented by process management and scheduling of production demands. A technical system has supersystems and sub-systems. A Process consists of different levels of processes and sub-processes. The description of the process as a technical system should be applicable for the whole process from order to delivery and for a particular operation in production.

3.1 Law of completeness of a technical system

In a pull production system, production only begins when there is demand for final products. The engine of the production process can be represented by order or deadline term. Transmission of order to real processing can be achieved by production planning and order scheduling. The object is material or product, which is changing during the processing operations. The tool is operations or actions in the process. The Control Unit of the process is then reporting and process management with information flow. Essential elements of the technical system for the general production process are shown in the figure (Fig. 2) below.

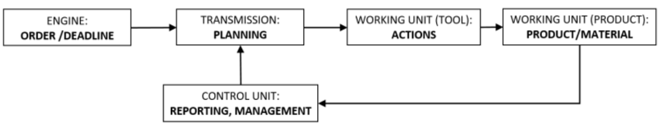

Fig. 3: Essential parts of a technical system for the production process

3.2 Law of energy conductivity in a system

The law of energy conductivity in a system or the law of the existence of links between parts of a technical system can be represented as links between operations in a technological process. Or just as a consequence of operations in production. From a value analysis point of view, transporting operations can be understood as links between value-adding operations.

3.3 Law of consistency of rhythm of activities of a technical system

The tact of operations represents the rhythm of the process. By balancing tact times, a rhythm of process is the same in the whole system – production process.

3.4 Law of increasing of the degree of the ideality of a technical system

Increasing process ideality can be represented by efforts to improve the process continuously. The degree of process' ideality can be calculated by equation (2) below

$$PI = \sum_{i=1}^{6} pPI_i = \sum_{i=1}^{6} \left(\frac{\sum_{j=1}^{n} B_j}{\sum_{k=1}^{m} H_k} \right)_i \qquad (2)$$

Where *PI* is a degree of Process' Ideality, *pPI* is partial ideality, *i* are six main aspects of the process (time, quality, costs, safety, ergonomics, and ecology), *B* is benefit, *H* is harm, *n* is a number of benefits for aspect *i*, *j* is a specific benefit, *m* is a number of harms for aspect *i*, and *k* is specific harm. [16]

3.5 Law of irregularity of system's part evolution

This law can be seen in the production process as an unbalanced process or bottleneck of the process. After improvement or innovation of one process in production, other processes are on a lower level, and the whole production system is irregularly evolved.

3.6 Law of transition to supersystem

When the process is improved or optimized, innovation can continue by the innovation of the supersystem – in this case, the whole production system or the whole company strategy. Then the rules are changed, and the whole production system should be able to innovate or to improve again.

3.7 Law of increasing of the degree of systems dynamics

Demands are more and more specific, and production goes into customization. That is why production processes should be more flexible, elastic, and dynamic. The law of increasing the degree of dynamics fits here too.

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3.8 Law of transition of a system from macro- to microlevel

There are tools for focusing on micro aspects of the process. Not only the macro state of the process, as process steps, but also operations or movements in the production can be improved. Predetermined motion time system tools such as MTM or MOST can be used to improve micro activities in production. This law can also be understood as dividing the overall process into smaller autonomous process units.

3.9 Law of decreasing the degree of human involvement

Processes involve more and more robotics, automatization, and autonomy systems. Industry 4.0 leads the way how to follow this law in production processes.

3.10 Law of increase of the degree of fragmentation

Hand in hand with a higher degree of dynamics of the process goes the fragmentation. Production cells and different concepts of production arrangements show that fragmentation law works for production processes too.

3.11 Law of increasing the degree of control over a system

More measurement, data collection, sensors, and automatized analysis of the production processes and operations give a higher degree of control over the production processes.

4. COMBINING OF TECHNICAL SYSTEM APPROACH WITH PROCESSES - SIPOC/9W

There can be several ways how to combine technical system thinking or its tools in process improvement efforts. One of the ideas is to combine the multi-screen diagram (9W) with SIPOC (supplier, input, process, output, customer). Each category of the SIPOC (or just IPO) diagram can be represented as a technical system, for the technical system, there must be sub-systems and supersystems. From that idea, a combined SIPOC/9W diagram can be constructed. See figure (Fig. 3) below.

Super-system	TS	TS	TS	TS	TS
System	TS (**S**)	TS (**I**)	**TS (P)**	TS (**O**)	TS (**C**)
Sub-system	TS	TS	TS	TS	TS
	supplier	*input*	*process*	*output*	*customer*

Fig. 3: Combination of SIPOC and 9W diagrams

After the basic SIPOC/9W diagram is done, another two ones can continue. Each technical system has its past technical system and its future state. By adding past and future states, a three-dimensional SIPOC/9W diagram appears. See figure (Fig. 4) below.

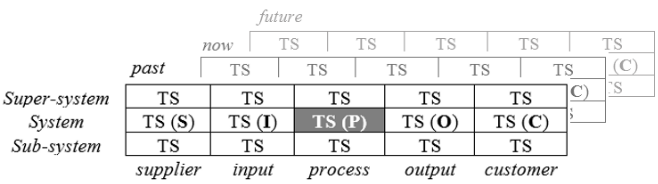

Fig. 4: Complete SIPOC/9W diagram

This combination should help to understand the evolution of the process itself but mainly technical systems around the process – not only sub-systems and supersystems but also previous and next processes. It also gives a better understanding of the evolution of materials and parts processed in the production system. This overall representation of the production system as a technical system and its surrounding in time and sequence leads gives many opportunities to see what and how can be improved or innovated in the whole production system. This combination helps understand the production system and look at it from a distance. The solver can easily understand what is the global optimum for the improvement efforts.

5. DISCUSSION AND CONCLUSION

In the chapters above, laws of technical systems evolution were used to determine of a production process as a technical system. As it can be seen, laws more or less fit the general production process. That is why the principles of TRIZ theory should be applicable in efforts for innovation of the processes. By following the laws of evolution, a production system can be innovated. For applying principles from TRIZ's laws of technical system evolution, there is good to understand how the process is described as a technical system. This can help to use evolution laws to process innovation more easily.

Also, the combination of SIPOC and Multi-screen diagram (9W) were combined together to better understand the surroundings of the production processes and their evolution ways. That leads to many ideas for what can be improved in the overall system. Each layer of the SIPOC/9W diagram must be presented separately because of its three-dimensional characteristic. Not every time a supplier or customer can be determined as a technical system, in that way only "IPO" is used. Still, it can be a very useful tool for finding a weak point, or the way what and how to improve considering connections between individual technical systems in the whole production system.

This paper could be used as a starting point for designing a new method or approach for the use of TRIZ for process improvement or innovation.

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