Tensions between Production and Engineering Units: A System Dynamics Model

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Abstract

In most research papers on process improvement, production unit and engineering unit are studied as a whole manufacturing operation. Engineering unit, as a technical bridge between R&D and production, is playing a uniquely important role. This paper argues that in order to explain some key organisational behaviour, the relation of production and engineering should be analysed because daily work is actually the compromise of tensions between production and engineering at the connecting point of vicious circle and virtuous circle.

Firstly, In this paper, process problems are grouped by two categories: technically-simple problems or technically-difficult problems, and short-term problems or long-term problems. Why quick-fix solutions are always selected for short-term and technically-simple problems is explained. Resolving technically-difficult and long-term problems is always the duties of engineering department.

Secondly, authors notice these two departments have both common goals and uncommon goals to seek, and account for different performance measurements. Potential conflicts are discussed and a basic SD model based on the phenomenon of fighting for resources is developed.

Lastly, by tracing the tension level from low to high, first order, second order and third order are added into the basic model to discover the negative impacts on process and quality systems.

Section 1. Introduction

Systems Boundary Thinking (SBT) is a topic being initiated and studied in the University of Auckland. As a strand of systems thinking, SBT focuses on the researches and practices around the concept of boundary through systems approaches. We are looking at why and how boundaries are built, shifted, opened or destroyed, and what is the state and what exchanges happen at the boundary areas, among sub-systems inside the "whole" system. SBT is a way of inquiring, that is, an engine in the iterative problem-solving process. For industrial applications, SBT is employed to analyse the consumption and synergy in between different departments, and the interface between an organisation and its environment. In this paper, we focus on the relationship (positive and negative tensions) between production and engineering departments.

In most manufacturing companies, engineering unit is positioned in between production unit and R&D unit. In Japanese companies, it is called Production

Engineering. In American companies, it is just called Engineering. For most firms in electronic industry, engineering unit usually consists of two groups, one is related to activities of product test and tester development, named as test engineering department, another is related to activities of process design and machine service, named as process engineering department.

Engineering unit performs a uniquely vital role in the transformation from a functional product to a manufactureable commodity and from its pilot-build to mass-production. Besides daily technical support, such as designing process, providing test solutions, and solving hard process problems and hard product defects, Engineering's duty also includes sustaining quality control, applying new technologies, preventing hard problems and improving process continuously (like Kaizen's idea) or discontinuously (like a step platform). Furthermore, the transmission of technical information between engineering and R&D can reinforce the reliability and testability of designed products, and introduce concerns for manufacturing in design stage so as to reduce the total cost in entire product cycle. This kind of thinking is very practical as well as meaningful. In many, in fact almost all, of the multi-national companies (MNC) in Southeast Asia, the R&D is located in the mother nation, thus the engineering function in the purely low-cost manufacturing base becomes more important in the production process of making a design realised.

However, in most research papers, production and engineering are not studied separately (see Repenning and Sterman (1999) and its articles quoted). Instead, the combination of two, or the manufacturing operations is always considered as an integrated unit. Engineering unit, as a bridge of production and R&D, is process designer, functional maintainer, quality stabiliser, technology carrier and information transformer. These functions are critical for preventing the decline in technical and quality requirements throughout the whole process from high-profile pilot run to low-cost mass production. Sometimes, supporting a particular product in engineering requires more resources and more knowledgeable engineers than that designing the same product in R&D.

People may argue that, you are very old-fashioned. We are now living in a post-modern knowledge society. A company should be "fluid", and behaves like a neural system, with metaphors of "organism" or "family". Employees and departments are free, autonomous, self-learned and self-organised. The parts of the machine, or the units inside an organisation, are no more noted because the functional differences are so "blur" that no one can tell the sub- but only the whole-system. There is no boundary at all.

However, sometimes to be old-fashioned is a way to maintain original value and prevent us from changing mindlessly by following fads blindly. What we believe is that, besides subjective mental improvements, there are some "objective" imperatives. Technology and accountability are two of them. It is proven in many fields (e.g. information technology) that technology is a key stabiliser to sustain a new way of doing things. As a technology carrier, deployer, transmitter, and transformer, engineering department cannot be ignored in the process improvement in at least manufacturing environment.

In the real business world, the accountability of the performance of a person, or a department is still one of the most important tools in measuring and organising. As long as the performance accountability of production unit and engineering unit is judged differently by superior management (plant manager or general manager), the study of their relations, or their co-operation, interaction and collision is necessary.

This paper is dealing with the relation through tensions between engineering

department and production department. Because we believe the duty of management is to convert negative tension into positive tension, psychological tension into creative tension, or vicious circle into virtuous circle. In Fig.1, "Manufacturing Operations" is tore apart into production and engineering units. And the tensions between the two will be studied in the following sections.

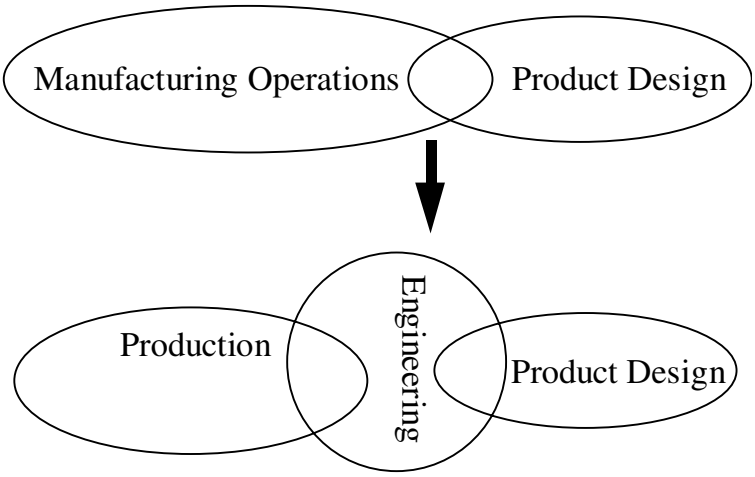

Fig. 1. The Position of Engineering Department

Section 2. A Basic SD Model of Manufacturing Operations

System dynamics (SD) is very valid in analysing industrial issues like process problems (Forrester, 1961). A basic model is built by Repenning and Sterman (1999) with the assumption that the manufacturing operations is a whole. It is discussed that, in a manufacturing environment, there is a causal loop of self-confirming attributions, or misperception of feedback, in which managers tend to believe the low throughput is due to the low effort of workers. Thus tighter control over these "lazy" workers is often implemented, and in turns, results in defensive behaviours, such as, ad hoc changes in process, unwillingness in doing preventive maintenance, and keeping of secret inventory. These behaviours can naturally introduce more process problems, more product defects, and less reliability of machines. At the end, the intention of increasing throughput will fail, followed by heavier inventory of Work in Process (WIP) and longer Manufacturing Cycle Time (MCT).

Process problems are grouped into two in this paper: technically simple problems/technically difficult problems, and short-term problems/long-term problems. To answer why quick fix solutions are always selected for short term and simple problems in production, a fact is worthwhile to be noted that engineering, not production, is the one that always has to take the responsibility of resolving technically difficult/long-term problems. As showed in Fig.2, in most manufacturing organisations, there is always an intuitive decision to locate resources for the quick-fix of simple and short term problems so that the immediate time/number targets (like throughput, or efficiency figures, or defect rates) can be fulfilled.

Of course, throughput is not the only target. Every plant manager or operations manager knows that he/she should meet objectives of both quality and throughput with limited resources. But many times, one is achieved by sacrificing another by following the immediate direction from top management and meeting the urgent requirements from customers.

In practice, experienced production managers can play around the internal

defect rate to hit throughput target, because they know the maximum throughput is neither obtained at the point of zero defect rate nor at the fastest line speed. By setting line speed at certain high level (but not the maximum) and, at the same time, repairing certain percentage of defects, they can get maximum output, or any result they want. One of the reasons behind is that internal defect rate can be something invisible to the direct customer in short term. The rework record is written internally by production personnel. Repaired products can pass the functional test but may not be as long-term reliable as first-pass products.

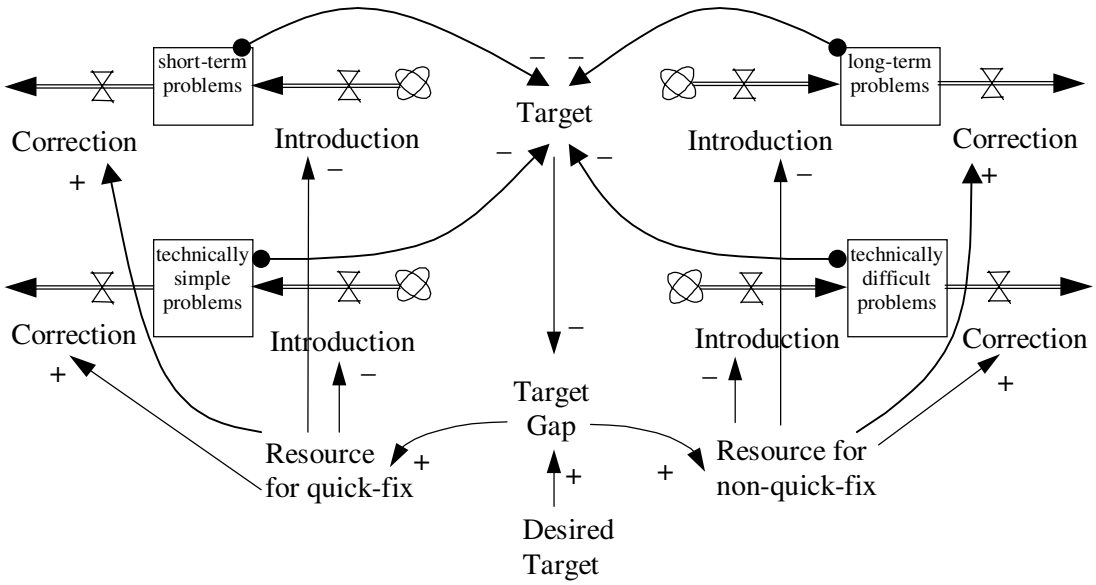

Fig. 2. A General SD Model for Manufacturing Operations

Some technically simple and short term problems:
1. Workers' laziness;
2. Simple defects;
3. Obviously wrong process setting;
4. Low throughput figures;
5. Constant failure during first-time testing/processing.

And their corresponding actions:
For 1. Making workers' work harder;
For 2. Low-level repairing work, or "touch-up";
For 3. Adjusting simple process settings;
For 4. Tuning line speed faster;
For 4. Calling for over-time;
For 4. Ignoring daily maintenance to create more machine time;
For 4. Generating and repairing simple defects;
For 5. Testing/processing one more time;
For 5. Rejecting the tester/machine and return it to engineering;

Some technically difficult and long term problems:
1. Poor productivity due to design problem (less concern for process in R&D stage);
2. Low reliability of final products due to internal repairing;
3. Hard product defects caused by design problems;

4. Hard product defects caused by ad hoc changes of process settings;
5. Marginal failures due to poor product design or poor tester design;
6. Intermittent problems due to poor design of processes or fixtures;
7. Machine ageing problems due to lack of daily maintenance;
8. Reliability problems due to lack of preventive maintenance;
9. Accuracy problems due to lack of calibration;
10. Inevitable human errors due to lack of process automation (or, too much manually process).

Their Corresponding actions:
Although these problems may be caused by either production, or R&D, or engineering, or a mix of them, almost all the problems have to be encountered and resolved by engineering department. This is because the purpose to hire higher paid engineers in engineering department is to resolve technology-intensive, complex and hard issues listed above.

Normally, engineering personnel, as a bridge, would communicate with R&D to raise design concerns for productivity and testability. Also engineering department has to automate processes, carry out preventive maintenance and calibration, improve the process setting, compile procedures, develop proper tools and equipment, by going through experiments and researches. All these are related to the hard/long-term problems in the manufacturing process.

In the next section, we explain how the different performance measurement for production and engineering results in the "nature" competition over controlling resources. And that may become the staring point of a 0-order tension of vicious circle.

Section 3. "Nature" or 0-order Tensions: Fighting for Resources

Fig.3 shows how production department and engineering department organise their limited resources in gaining their respective performance credits. Production is accountable for of both throughput and smoothness of process, and engineering for both significant process improvement/problem prevention and smoothness of process.

Usually, besides people to do on-line jobs, production remains a small non-on-line team to repair simple defects, to carry out daily maintenance and simple services. This small team comprises of several technicians and skilled operators and is vital for the daily smoothness of process.
Engineering which is made up by a batch of engineers and technicians has to put efforts on both daily technical support and experiment/development. The daily supporting jobs include teaching production staff in new technical issues, repairing difficult defects (together with production), fine-tuning machine settings and procedures, solving hard process problems, dealing with special quality issues, improving on-line tools, fixtures and testers, taking care of the pilot run of new products. In most of the case, engineering does not set up a separate daily support team (for resource utilisation purpose), and its staff, being normally highly educated, have to take care of significant process improvement/problem prevention issues at the same time. (Only when the job can be converted into simple and routine work, technicians in production's non-on-line team can be trained to take over it.) Some examples for significant process improvement/problem prevention are like: the automation of line process and testing process, in-depth training for self and

production, preventive maintenance and calibration, and the exchange of technical information with R&D.

On one hand, the resources (i.e. machines and testers) for process/testing improvement and experiment are mainly controlled by production. On the other hand, engineering's resources are partially distributed in daily production support. That means if there are many hard production issues, such as, hard defects and complex process problems, engineering's human resources will be very much occupied. Hence the performance of engineering department does not just depend on itself, but very much the co-operation of production.

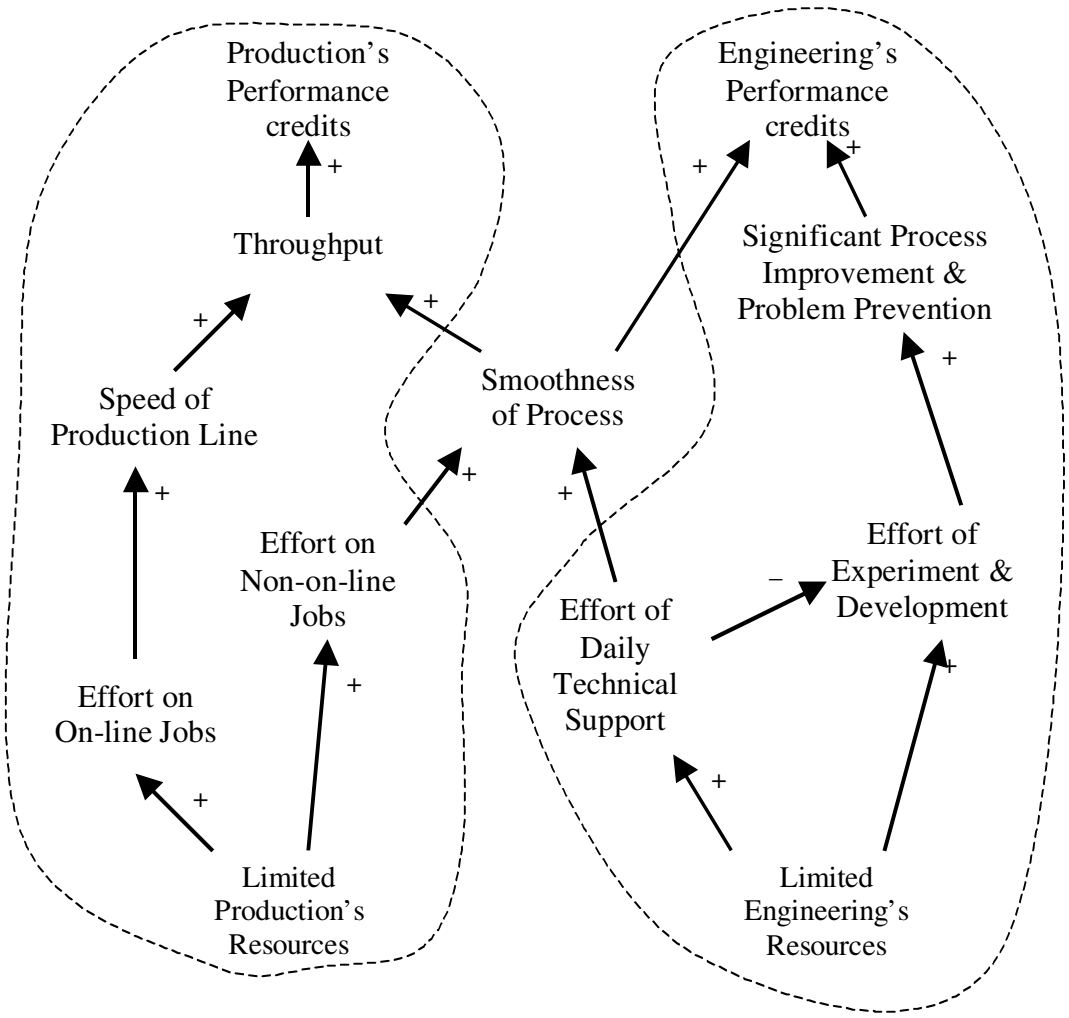

Fig. 3. The Different Performances Credits of Production and Engineering

In general case, production receives technical support from engineering and, as a return, provides necessary process time and resources for experiment and development issues handled by engineering. But when the resource is scarce or when the pressure (from top) for throughput is overwhelming, production tends to increase the line speed and concentrate on on-line jobs, pushing more problems to engineering by simply indicating "these are technically difficult problems". This is usually an "effective" approach for production to save its own resources by making use of engineering's resources in defect repairing and process problem-solving. This phenomenon happens because (1) production's main performance is judged by

throughput; (2) both engineering and production have to account for the smoothness of process; (3) the performance achievement of engineering very much relies on the facilities and resources controlled mainly by production, that is, engineering becomes "second citizen". All these factors may actually generate potential tensions between the two units.

Section 4. Vicious Tensions vs. Virtuous Tensions

Fighting for resources and performance credits can generate tensions between production and engineering. But tensions may not necessarily lead to a vicious circle. Sometimes, production and engineering work together and convert the tension into so called creative tension in a virtuous circle, which can compete with each other towards higher standards of performance. This dialectic relationship shows in Fig. 4 Vicious Circle and Virtuous Circle.

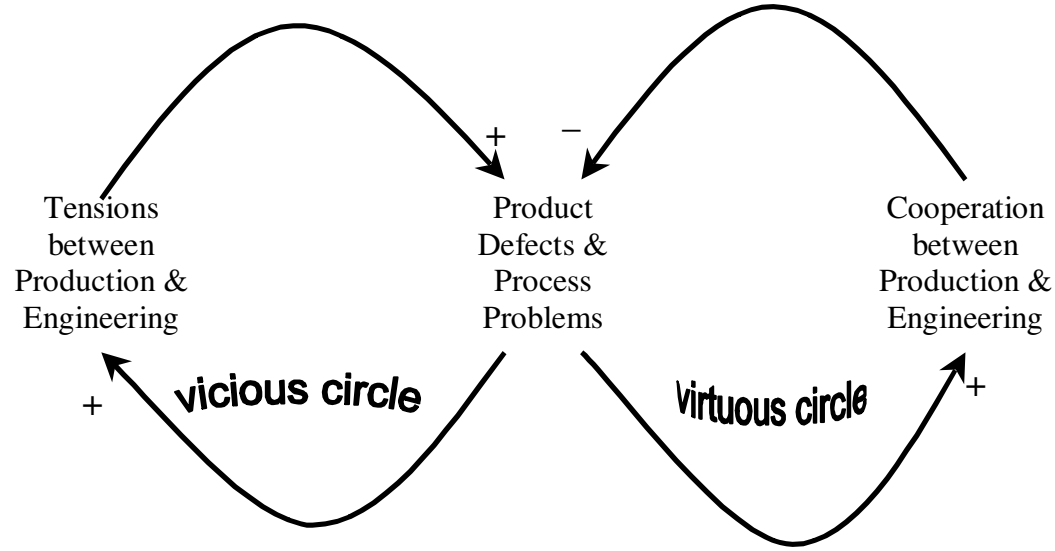

Fig.4. Vicious Circle and Virtuous Circle

Since the causes of the tension have been discussed, the next task of this paper is to model variety of vicious tensions with all the relevant organisational behaviours and situations. The basic behaviour that production and engineering dissatisfy to each other may lead to higher tension intensity. When tensions increase, each accuses the other to be responsible for the "bad" consequences, that is, more process problems and abnormal defects. Each side is unwilling to support to each other, then again, make tensions worse. This "worse and worse" cycle, explained in Fig.5, is the basic model of the vicious circle. This together with Fig.3 (different performance credits of production and engineering) will make up the 1st order of the vicious loop in the next section.

When the pressure over production on throughput becomes higher and higher, production may even purposely convert technically simple and short-term problems into technically difficult and long-term problems to push the load away. This situation is illustrated in Fig.6. For example, production can ignore daily machine maintenance, thus may cause machine reliability problems and even breakdowns at later stage. Production may also remove some restrictions in the process procedure to run faster operation, thus may induce a small amount of hard defects without affecting the immediate output number. These very vicious behaviours shown in

Fig.6 will make up the 2nd and 3rd orders of the vicious tensions in the next section.

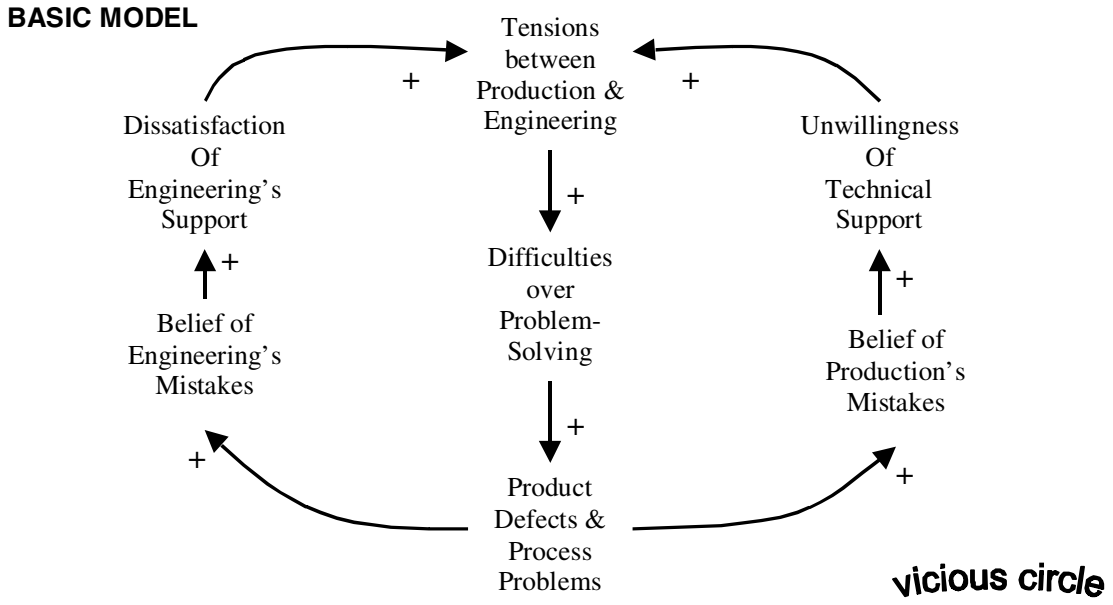

Fig.5. A Basic Model of Vicious Tensions between Production and Engineering

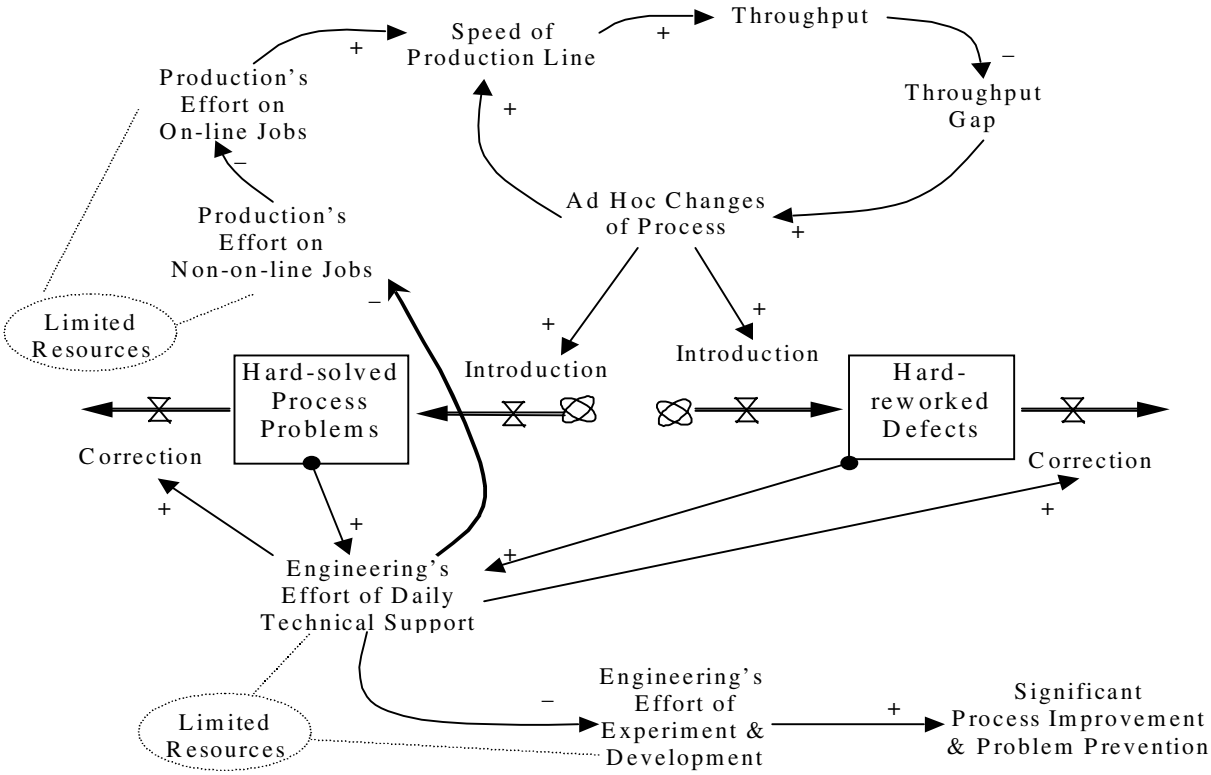

Fig. 6. Hard Problems and Hard Defects due to ad hoc Changes of Process

Section 5. Increasing Tensions: Order 1, 2, and 3

The tension created by fighting resources is still a nature or 0-order tension. It is nature because it is the nature of human beings and organisations in competition when there is interest conflict due to limited resources. When pressure becomes higher and higher, however, due to high competition or unrealistic requirements in an abnormal environment (for instance, in transformation or crisis), vicious tensions appear and increase if they are not handled properly.

By combining Fig.3 (different performance credits of production and engineering) and Fig.4 (a basic model of vicious tensions), we deduce Fig.7 which is the first order of tensions between production and engineering. In this order of causal loop, the tensions are caused by fighting resources between production and engineering for their own performance credits. Production puts less effort on non on-line jobs and tries to consume more engineering's resource of technical support. The circle turns into vicious. But it is still not so bad. This is because in a co-operative context, resources can be relocated from one department to another to seek the urgent goals. In order to do this, a good negotiation between production and engineering is needed. And since production is the controller of most of time and process resources, the head of production should have a long-term and holistic mind-set.

Unfortunately, in many companies, that is not the end of the story. Because some managers are short sighted, and some top managers only know reinforce pressure to meet short term targets, tensions between production and engineering increase. Production would try to hit numbers by hurting others.

In Fig.8, the second order of the vicious loop is depicted by adding several double lines which show production's "bad" behaviour “unwillingness to release process time and resource”. This sacrifices the activities of significant process improvement and problem prevention to be performed by engineering. Usually engineering personnel has no choice but to delay its own development projects to help on “the smoothness of process” which also contribute to its performance credits.

When we study and add the "very bad" behaviours of production (see Fig.6: Hard Problems and Hard Defects due to ad hoc Changes of Process), we come to the next order (or 3rd order) of the causal loop shown by triple lines in Fig.8. This time production becomes really “vicious” when it either cannot stand the extremely high pressure from top management, or the factory is suffering from the radical re-engineering or transformation. For its own throughput target, production even skips some necessary procedures, or operates machines in an "ad hoc" way, hence leaving hard defects and hard problems to engineering department. Engineering has to locate unwillingly more and more its resources into the daily support and problem-solving. But normally in such a situation, the process can never be smooth, due to the mis-use of machines and procedures. And there is little time reserved for engineering to work on technical development. Thus, engineering cannot get any performance credits at all. The Tensions between these the two units change to real collisions and conflicts. As a result, huge psychological anxiety and anger will be generated. A political struggle for powers and interests may begin.

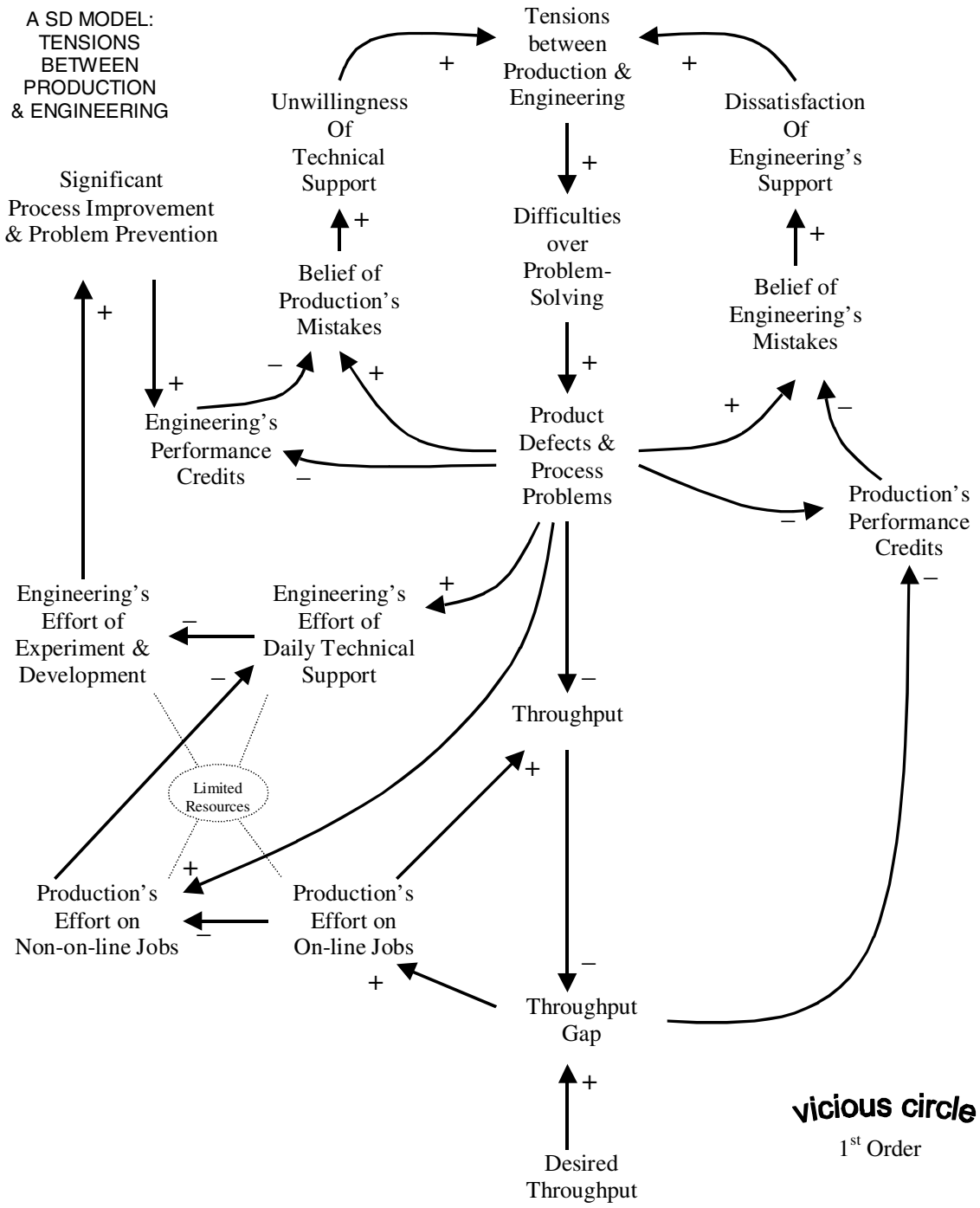

Fig.7. 1st Order of Vicious Circle: Tensions between Production and Engineering

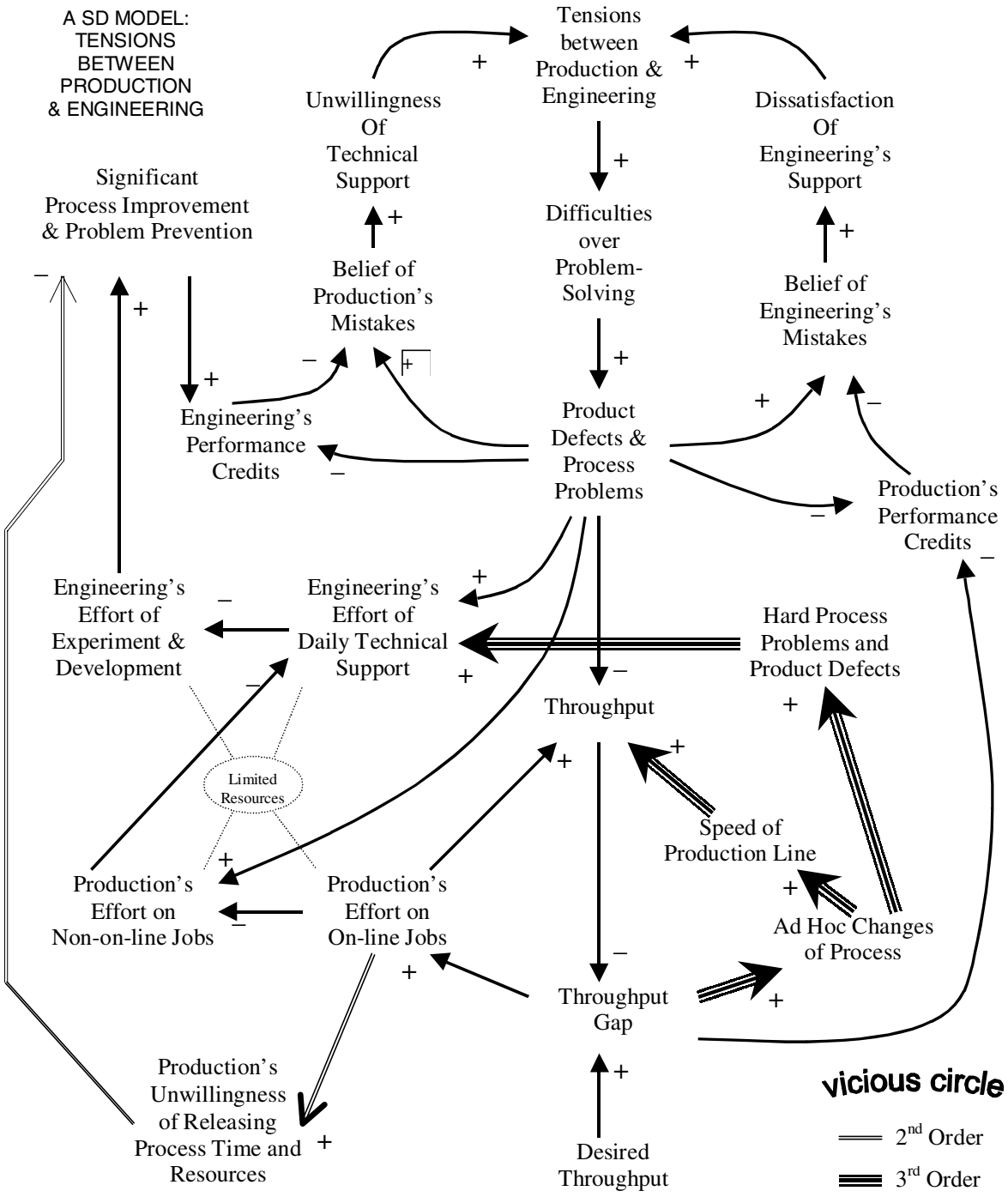

Fig.8. 2nd and 3rd Order of Vicious Circle:
Tensions between Production and Engineering

Section 6. Conclusion

This paper is one of the applications of Systems Boundary Thinking (SBT) and focuses on the tensions at the boundary in between engineering department and production department in a manufacturing environment. In the current subjective, interpretive, and soft academic atmosphere, the authors try to add a bit of objective, critical and hard elements derived from our in-depth understanding and practice in the manufacturing context.

Tensions are always there, in particular, at the boundaries among units whose performance are measured differently. The creative tensions could become positive drives which output innovation and collaboration. The psychological tensions due to abnormal pressures and political conflicts might result in negative contradictions and low productivity. The former is the starting point of a virtuous circle, whereas the latter a vicious circle. In the beginning level (0-order) of vicious circle, fighting for resources to gain more performance credits is understood as the nature of any competitive organisations and individuals.

In the real business world, this vicious circle sometimes might grow with very intensive tensions. The causes for such a phenomenon could be extremely high competition, or unrealistic requirements, or the fact that the business is suffering a radical re-engineering process, or the fact that the business is experiencing an turbulent environment (for instance, an economic crisis).

When the tension level goes up, the number of orders of the vicious circle increases. From the first to the third order, this paper analyses the tensions between production and engineering departments. Different companies may have different level of tensions. The level of tension is changing from time to time in a dynamic and dialectic way. Departmental and personal interests are involved. Organisational objectives and cultural factors are concerned. Eventually, in most of the cases, a compromise can be reached in some form of implicit or explicit agreements. The reduction of the tension level, or the fast reaching to a balance point, or the transformation from vicious circle into virtuous circle is the duty of the management. This challenging task requires means more than just applying subjective disciplines or paradigmatic models. It can be a real test of the level of wisdom, not just knowledge of managers in the decision-making process under high pressures.

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