The complete kit concept

B. RONEN†

One of the fundamentals of good operations management practices that is rarely discussed in the literature is the 'complete kit' concept, which suggests that work should not start until all the items required for completion of the job are available. These items (the kit) include components, tools, drawings and information. Starting a job with an incomplete kit means more labour time to finish the job, longer lead time, more work in process, reduction of throughput, poor quality and impairment of due date performance. The paper analyses the various facets of the complete kit concept in manufacturing, research and development, engineering and service organizations.

1. Introduction

Three hundred components are required to complete the assembly of a certain printed circuit board (PCB). The foreman of the operation has a very tight schedule, whereby he has to rush a delivery of 50 units (PCBs) to an internal customer, who is pressuring him to get the work done as soon as possible (that is, yesterday...). His 20 production people are fully loaded with all kinds of PCB assembly work. So far the purchasing department has on hand 298 of the 300 components required. The foreman's boss suggests releasing the order to the floor, starting to assemble, and adding the other two components later. This seems reasonable, as the purchasing people have already assured the foreman that the missing components are on the way, pointing to certain magic airway bill numbers as proof. The end of the story is only too familiar: the 50 units are already assembled, and waiting for the missing components that have not yet arrived. Other jobs that were put aside to make way for this hot order have not been delivered on time, and are still waiting in line. Two weeks later, upon arrival of the missing components, the foreman, with the help of his boss, shortcuts all incoming inspection procedures and assembles the components manually on the waiting PCBs, which then fail the inspection because the two missing components were incorrectly placed.

Sounds familiar? Clearly working with a complete kit (CK) would have led to the fastest productivity gain, as it would in most types of manufacturing, engineering, research and development, service and paperwork environments. It is surprising then that so little has been written about this important issue and that it has not become a subject of popular debate. Taking it for granted that this is the way everybody works, just-in-time (JIT) adherents such as Schonberger (1986) and Suzaki (1987) pay very little attention to it. Proponents of total quality management (TQM) (Deming 1986) relate to it only implicitly by saying 'do it right the first time and on time'. The theory of constraints (TOC) does not address the phenomenon at all.

CK methodology and its theoretical background is easy to understand and not difficult to implement. It is easy to adopt in every environment and situation, providing much benefit in a relatively short time.

Received December 1991.

† Tel Aviv University, Faculty of Management, University Campus, Ramat Aviv, Tel Aviv 69978, Israel.

0020–7543/92 $3·00

What is a complete kit? A complete kit is the set of components, drawings, documents and information needed to complete a given assembly, subassembly or a process. A complete kit is the readiness of the kit prior to release to the shopfloor.

At the same time, it is not necessarily the entire set needed for completion of the final product. An example will serve to illustrate this distinction. If one is assembling a full radar, a complete kit is not all the 30 000 items needed for the completion of this product, but, for example, those needed to make one of its PCBs. Such a kit contains 300 components, five drawings, and an acceptance test procedure (ATP).

There are two types of kits. The inkit is the kit required as an input to the operation. The outkit of a given operation may be the inkit of the next stage. For example, plant A of a conglomerate manufactures parts for plant B. The inkit of plant B is seven different units. Thus, supplying six out of the seven parts will not advance the production of plant B, and plant A's outkit should be seven units. Unless otherwise noted, the term kit in this paper refers to an inkit.

This paper analyses the complete kit concept and its implications for better operations management.

2. The 'evils' of an 'incomplete kit'

Understanding the evils of working with a incomplete kit is very important.

More work-in-process (WIP)

Using an incomplete kit causes more work in process, because the job is invariably waiting for additional components to arrive. Only too often products pile up at the final station waiting for documents or ATPs, creating more WIP in the system.

Longer lead time (LT)

The relationship between the level of WIP and the production LT has been widely discussed (Schonberger 1986): more incomplete kits cause more WIP and hence longer lead time. Moreover, the practice of using an incomplete kit causes more setups (you do the work twice) and the double handling means more time per part is spent. Since lead time is considered to be a source of tactical and strategic advantage to the company, it is extremely important to use any method to reduce it to a minimum.

High variance of quoted lead times

It is very difficult to quote a lead time when a major item of information (when the missing items will arrive) is unknown and difficult to predict. Deming (1986) considers high variation to be the top enemy of production.

Poor quality and more rework

Much work-in-process causes poor quality performance. Incomplete kits tend to wait in inadequate storage facilities for too long. When the missing items arrive, they are incorporated in an improvisatory fashion that may give rise to quality problems. The double handling undoubtedly causes damage to the product as well as to the process, usually adding more rework to the operation.

Decline in throughput

An item that is processed without being sold is not considered throughput. When resources are utilized on products that cannot be shipped, other jobs that can turn into throughput have to wait.

Decline in productivity

As noted, using an incomplete kit increases both setup times and the required time per part. Our experience in manufacturing shows that releasing an incomplete kit to the floor means spending 40% more working hours than working with a complete kit. In a paperwork environment the inefficiency factor is assessed to be around 80%. Experience in research and development (R&D) processes indicates a similar inefficiency figure.

More operating expenses

High WIP causes more operating expenses on account of more holding costs, more scrap and more work put into the job. As noted by Schonberger (1982), any operation that does not add value to the proces is a waste. Bad quality costs more money, as we have to do more rework (Deming 1986). Double setup (be it on the mental, physical or managerial level) adds more expenses to the process.

Decline in workers' motivation

Using an incomplete kit goes against the grain. It is the 'hurry up and wait' way of manufacturing. Once the 'red hot' incomplete kit arrives it gets top priority. Then, it waits till the rest of the items arrive.... Regardless of their education and training, and the level of complexity of the work they are doing, the people on the job are not stupid. It hurts their motivation and trust in the system when they are forced to do more and apparently unnecessary work (double setups and more handling).

Increase in complexity of controls

If one works using an incomplete kit, the control of the system becomes very complex, and sometimes almost impossible. A simple flow chart becomes inordinately complicated when incomplete kit activities are permitted. Batches on the floor do not move as fast as they could. More storage area is required and the production manager is at a loss to explain how he reached this impasse.

Less effort to ensure arrival of the missing kit items

Releasing an incomplete kit to the floor gives both the customer and the producer the illusion that every effort is being made to get the job done. They then tend to relax their efforts to ensure the speedy arrival of the missing items of the kit. (Experience shows that in places where a CK is a part of the culture, missing items are received faster.)

3. What prevents people from using a CK?

If the benefits of using a CK are so obvious, why is it not used all the time?

The answer is that certain major obstacles lie on the way to using a CK.

Efficiency syndrome

The efficiency syndrome is the urge to have your resources utilized as much as possible. Following the fallacious notion that a worker should be busy all the time causes managers to have their people working using incomplete kits just so that they should not be idle. More importantly, it also means more WIP, less throughput and more operating expenses (Goldratt and Cox 1986, Ronen and Starr 1990).

The basic remedy for the efficiency syndrome is a major managerial change in the organization. Such a change includes the introduction of TQM, TOC or JIT. Thus, a CK practice works better as part of a total management philosophy. In fact, the CK concept and techniques are part of the methods and philosophies of a JIT/TQM implementation.

The efficiency syndrome is counterproductive if the operation has either an internal constraint (bottleneck resources) or an excess capacity. In the bottleneck environment, there are always other jobs that can turn into an immediate throughput. In cases where the operation has excess capacity, there is more pressure to use an incomplete kit, just to utilize the resources. There is no justification whatsoever for this, since excess capacity means shorter lead time; thus there is virtually no advantage to start working in a incomplete kit mode.

Pressure for an immediate response

When the customer puts pressure on the manufacturer to start working on his or her order even if the kit is not complete, in the mistaken belief that lead time will be saved by this action, in practice, this only adds to the lead time. It is well recognized (Schonberger 1986) that the process time is only a small part of the total lead time, perhaps $< 1\%$. If, for example, the process time for assembling a PCB does not exceed 4 h, and the total lead time is 4 weeks, the best thing to do is to wait for the complete kit, and give the job top priority for quick assembly once the missing items arrive. And what happens in practice? Because of the pressure exerted by the customer, and the foreman's anxiety to show his or her goodwill, the job is put to work immediately. All 4 h are put into it, and then it waits for the missing items. Once they arrive, another 1–2 h of work are added. The result is more operating expenses, and usually no lead time saved.

Anxiety to show goodwill on the part of workers and foremen

As a result of management pressure, the line people express their goodwill by releasing incomplete kits to the floor.

Inadequate allocation of levels of assembly

The trend today is to reduce the number of levels of assembly. This, in turn, may cause the number of components per kit to grow to a level that is difficult to control and almost impossible to gather together at a given time.

Misleading material requirement planning information on lead time

The lead time in MRP systems is long and consists of production time as well as waiting time. This gives the illusion that the operation will take a long time, and leads to the faulty conclusion that the earlier a start is made the better.

4. The CK concept in different environments

We will now show the CK concept in action in various areas.

4.1. *CK in manufacturing*

Manufacturing is the area in which the CK concept is most popular. Here, the CK has two major components—hardware and information—and we can define certain rules for its effective use.

Rule 1: Do not start the assembly unless the kit is complete. Assign one person (the 'gater') to be in charge of the CK. The functions of the gater are as follows:

- He/she allows only the release of jobs that need to be produced according to the schedule.
- He/she audits the batch sizes and ensures that only small lots that conform with the demand (according to the JIT philosophy) are released.
- He/she releases materials, monitoring the buffers on the floor. Once the buffers are 'full', he/she should not release more WIP to the floor (Goldratt and Cox 1986, Ronen and Starr 1990, Schragenheim and Ronen 1990).
- He/she makes sure that only CKs are released.

Thus, one of the jobs of the gater is to take charge of completion of the kits.

Rule 2: If the process/assembly or subassembly time exceeds 50% of the total lead time, the levels of assembly should be redefined.

The following example will illustrate the meaning of rule 2. In a certain operation, the total lead time is four weeks, while the process time is a three week period. The work includes manual processing of electronic wires, which takes up almost the entire three weeks, and the assembly of the connector. If the connector is missing, starting with an incomplete kit may be good judgement for meeting a tight schedule. The kit should therefore be redefined for a smaller number of components: the manual processing should be one level of assembly, while adding the connector is another one. Thus it becomes very convenient for the manufacturer to have another three weeks to worry about the connector, and start working on the manual processing, which is now a CK. One may question the importance of redefining the kit, when the same work is being done anyway. The main reason is that an appropriate storage place will be assigned to the kit, and the connector can be legitimately assembled later on.

Rule 3: All entities needed to complete the process are included in the kit.

Should the manufacturing drawings, for example, be considered part of the kit? The answer is definitely yes. These drawings are needed to begin the process. Should the acceptance test procedures be included? They certainly should be, since they are part of the assembly. The same goes for route cards, recipes, method cards, etc.

Note: It is often asked whether a CK should be used in the production of an engineering prototype. The answer is definitely yes, though the kit is quite different. It should be a prototype kit, which is less structured than a production kit.

4.2. *CK in R&D*

In R&D activities the CK is a set of information items in all the different media needed to complete the job. In many cases the engineer or the technician starts working using an incomplete kit of information. This is one of the reasons that most development activities are carried out twice or three times. While the notion of a CK is not new in industry, it is something of foreign concept to R&D people. To implement the CK concept one has to define small tasks and the kit that is associated with each task. By the very nature of their work, this is alien to most R&D people.

Other facets of the CK in R&D include budget, specifications, due dates and ATPs, as well as interfaces with other modules.

4.3. *CK in engineering*

The engineering function transfers R&D's drawings into methods and production tools. It is the interface between development and production. The assignment of a gater who will be responsible for the CK implementation is the main step toward success. The CK also includes methods, fixtures, drawings, budget and time tables. The engineering function is different from the R&D function, the engineering being more deterministic and more similar to the production process. The engineering function also has the additional job of making production work with complete kits. This is done by building procedures that will not allow the manufacture of a part that does not have a CK.

4.4. *CK in service organizations and paperwork environments*

In paperwork environments the rule is to start working only if the kit is complete. For example, the purchasing department will not start working unless the kit includes all the documents and information needed (i.e. end-user approval, budget number, necessary drawings, etc.). In a life insurance department, this means that no insurance policy is going to be issued unless all documents are ready. In both examples a gater is assigned, and he or she is the only person authorized to release jobs to the office floor. Clearly you cannot finish the work if you are missing a document or a form. The main point is not to start until all the documents are on hand.

4.5. *Customers' reactions to the CK concept*

Both internal and external customers have to be educated and trained to understand the CK concept. This training and education can be carried out as part of JIT, TQM or TOC programs. Experience shows that most customers who bring an incomplete kit for processing and whose jobs are therefore not accepted, return in a very short time with a CK. When you have no choice, you tend to find the missing items, usually in the engineers' drawers.

5. How to implement a complete kit philosophy in the organization

Modern management philosophies and techniques support the CK concept:

5.1. *JIT support*

JIT suggests doing the right things on time. An incomplete kit is viewed as theft. The 'stealing' phenomenon has two facets: if one works on something that cannot be delivered to the customers, time has been stolen from products that could have been produced (real throughput) and are waiting because the resources are being utilized for work on incomplete kits. The other facet is the 'stealing' of components. In many cases, when an incomplete kit is released to the floor, an urgent order arrives. This order cannot be completed because some components are missing. Unfortunately these components are being assembled in another incomplete kit, that cannot be supplied either... . Far from the view of the customer and the quality people, a 'cannibalization' process starts: components are brutally moved from one semi-product to the other, causing quality damages.

JIT also preaches reduction of WIP, and a CK is one of the most effective means of achieving this end.

JIT emphasizes the notion of small lots. Using small production lots enables the use of CKs. The smaller the lot the more likely it is to achieve a CK. Preventing double handling and double setup, as well as the ensuing waste, go hand in hand with the JIT philosophy.

The Kanban technique supports the small-lot concept; an incomplete kit cannot go through the gating operation.

5.2. *TOC support*

According to the TOC (Goldratt and Cox 1986, Ronen and Starr 1990) the goal of an organization is to increase net profit in the present as well as in the future. Increasing throughput, defined as the money the system makes through sales, would seem to be a natural way of increasing net profit, and a job that cannot be turned into sales (such as one with an incomplete kit) is not considered throughput. In the TOC terminology, working with an incomplete kit is considered a policy constraint and should therefore be eliminated.

5.3. *TQM support*

An organization that works according to TQM principles will soon come around to adopting the CK concept. Along the route to improving processes, a major cause of negative effects (like high WIP, missed deliveries, etc.) can be traced to the use of incomplete kits. TQM tools—control charts, the Pareto diagram and others—can maintain and monitor the CK process. The TQM control cycle will support avoidance of the incomplete kit. A control chart of the process lead time will detect the exceptional batches. A cause and effect diagram will get at the root of the problem: an incomplete kit. A Pareto diagram can show the main contributors to the phenomenon (either classification by customers or classification by the missing items). Reduction of lead time, monitored by the appropriate control chart, will show the improvement.

5.4. *Implementing the complete kit philosophy in the organization*

The following steps are suggested to implement a CK process.

(1) The introduction of a CK process has to be part of a major change in the organization. It has to be part of a JIT, TQM or TOC implementation.
(2) Top management has to be involved in the process. Without the support of top management there will be tremendous pressure from second-line managers to start processing incomplete kits, in the belief that this will speed up the work.
(3) One person has to be appointed in each department to be in charge of this subject. Usually it is the gater, that is, the person who releases the kits to the floor.
(4) The process must be monitored: Pareto charts need to be drawn, classifying incomplete kits by customers, projects, departments or by the missing components. Using cause and effect techniques (fishbone diagrams, effect-cause-effect, etc.) the reason for the discrepancy is sought and the corrective actions applied. The usual TQM way of improving processes may be employed here with good effect.
(5) Employees and internal customers need to be informed of the change. Several organizations that have adopted the concept have designed special workshops to cope with this issue. The use of personal computer simulations and demonstrations using special software, as well as demonstrations using the Siman software have been introduced into the educational process.

(6) External customers should be notified that they will get better due date performance and better quoted lead times if they submit a CK.
(7) The term complete kit should be redefined from time to time according to the circumstances. A good rule is—work smart and beware of inertia.
(8) Components and materials should be ordered in complete kits. Instead of ordering batches of the same components, the manufacturer should order a kit from his supplier. This applies to both internal and external suppliers.
(9) Operations should be synchronized, ensuring that the outkit of the current operation is the inkit of the next one.
(10) Components and procedures need to be standardized and common assembly parts used whenever possible. The more standard items in the bills of materials, the more likely it is that a CK will soon be available.

5.5. *Implications for computerized integrated manufacturing (CIM)*

The design of CIM systems should enable the automatic systems to work using a CK only, and disallow alternative routes.

5.6. *Implications for management information systems (MIS)*

The MIS department in the organization has to support operations with certain tools to enable a CK. Thus, a kit management procedure should be developed.

(1) *Kit requirements.* The CK is not only the items bought by the organization. It also includes the entities made in other departments, as well as the required documents, drawings and procedures. In most organizations it is difficult to obtain such a 'kit list' in one shot.
(2) *Logical search.* Before assembling the items in the warehouse, one should conduct a logical search and validate that they are available. Assembling incomplete kits (even when withholding their release to the floor) is almost as bad as working with an incomplete kit. Once the kit is assembled, the raw material file is no longer up to date, and it is this that causes the 'stealing' phenomenon and other evils. The logical search has to be supported by a good information system.
(3) *Physical search.* Only when the logical search is positive, can a physical search start.
(4) *Completeness check.* This should be done prior to the release.

5.7. *Implications for the purchasing department*

The purchasing department has to change its procedures according to the CK concept:

(1) It should purchase CKs. The orders have to be in kits rather than in components.
(2) This will force the purchasing department to work with less suppliers and purchase more items from each supplier.
(3) Suppliers will be measured not only by the lead time and quality, but also by the completeness of the kits.
(4) More raw materials and components will be purchased through jobbers.
(5) More raw materials and subcontracting units will be purchased as full complete units. For example, the company should purchase less single items and more complete subassemblies. This will enable a smaller kit and thus, more probably, a complete one.

6. Field results

A study of 30 organizations that have implemented the complete kit concept shows that using this concept has reduced WIP and cut lead time by a factor of three. In manufacturing, using a complete kit, together with small lots and drum-buffer-rope scheduling (Schragenheim and Ronen 1990) as well as gating, has led to a doubling or even almost tripling of throughput.

In one life insurance agency, using the complete kit concept decreased the number of 'open files' (namely WIP) from 1250 to 240 within a period of two months.

Preliminary results on the introduction of the concept in R&D processes show a major improvement in operations, though it is too early to make comprehensive measurements and assessments.

7. The complete kit as a planning and control system

Using the CK concept forces managers to better plan the tasks and the components of each task. Thus, the CK plays a major part in the planning process. Many actions are derived from the CK in planning: statement of the kit parts, task definition, lot size, definition of tooling, etc.

A lot of benefits are gained from using the CK concept as a source of the organization's control actions. Control points occur usually at the end of the process (planned vs. actual, etc.). In our case, control is done at an early stage of the process. It is done at a critical point, at a time where corrective actions can still be taken. For example, Pareto analysis of the insurance agents that did not submit a CK can start an improvement process by looking into the causes and creating solutions. Pareto analysis of the missing items in a manufacturing facility can be a trigger for corrective actions. The completion of kits before they are needed is also a source for investigation. Thus, the CK goes hand in hand with the TQM concepts of ongoing improvement. Moreover, by using the kit area as a control point we focus on things that disrupt our throughput.

8. Conclusions

The complete kit concept is a well-tried and trusted manufacturing procedure with considerable potential for improving both production and service operations. It can be used to gain a strategic competitive edge because of the faster response time, lower prices and better quality.

People have said: it is so obvious, what is there talk about? The answer is that most manufacturers and service organizations do not use it on a regular basis.

Some have said that it is important for others, but does not apply to them. Our experience shows that the complete kit concept can be applied anywhere. Experience in training and educating executives, managers, foremen and line workers shows that in many cases the practitioners need a formal framework even though their intuition about the CK is good. They need a theoretical background and methodological framework such as those presented in this paper to better cope with the pressure on the part of bosses and customers to start working with an incomplete kit. Many workers today do not have the backing to say no to an incomplete kit. The intention of this paper is to supply such backing.

The complete kit does not introduce any new theory to the field. It does however present a different perspective. For instance, the manufacturing trend today is towards fewer levels of assembly in the process, and this forces the manufacturer to use large kits. Thus the temptation to work with an incomplete kit is growing commensurately. Our view may indicate that benefits are to be derived from looking at the problem from another perspective.

Acknowledgments

The author wishes to thank Mr Ron Gur, Mr Shimeon Pass and Dr Avi Nir for their enlightening comments.

References

SCHONBERGER, R. J., 1986, *World Class Manufacturing* (New York: Free Press).
SUZAKI, K., 1987, *The New Manufacturing Challenge* (New York: Free Press).
DEMING, W. E., 1986, *Out of the Crisis* (Cambridge, MA, MIT, CIAS).
SCHONBERGER, R. J., 1982, *Japanese Manufacturing Techniques* (New York: Free Press).
GOLDRATT, E. M., and COX, J., 1986, *The Goal* (Croton-on-Hudson, NY: North River Press).
RONEN, B., and STARR, M. K., 1990, Synchronized manufacturing as in OPT: from practice to theory. *Computers and Industrial Engineering*, August, 585–600.
SCHRAGENHEIM, E. M., and RONEN, B., 1990, The drum-buffer-rope shop floor control. *Production and Inventory Management*, Third Quarter, 18–23.