UDK 658.56:006.06

Načrtovanje zanesljivosti izdelkov in proizvodnih sistemov z upoštevanjem analize mogočih napak in njihovih posledic

Planning of Product Reliability and Production Systems by Using Failure Modes and Effects Analysis

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Gospodarski uspeh industrijskih podjetij določajo dandanes predvsem majhni proizvodni stroški, kratek dobavni rok in zagotavljanje ustrezne kakovosti izdelkov. Vsi trije dejavniki so vključeni v celovit sistem zagotavljanja kakovosti, ki upošteva predvsem potrebe in zahteve uporabnikov ter omogoča podjetju uspešnost na današnjem konkurenčnem tržišču. S tem namenom moramo v podjetjih uvajati in uporabljati preventivne metode zagotavljanja zanesljivosti, s katerimi napake pravočasno napovedujemo in seveda ukrepamo, da bi preprečili njihov nastanek.

Ustrezne metode omogočajo določitev potencialnih nevarnosti, analizo in pripravo za preprečitev ali ublažitev učinkov oziroma posledic napak. Z uporabo analize zanesljivosti lahko pridemo do varnostno tehničnih postopkov, s katerimi lahko zanesljivost proizvodnih sredstev dokaj natančno ovrednotimo.

The economic success of industrial companies today is defined by low production costs, short delivery times and reliable product quality. These three factors are included in an integral quality assurance system which primarily takes into account the needs and the requirements of customers, and consequently enables the company to participate efficiently on the competitive market. To this end preventive quality assurance methods should be used in companies. They serve to anticipate potential failures in time and to prevent their occurrence.

Appropriate methods assure the determination of potential risks, and the analysis and the prevention or moderation of failure effects. Reliability analysis leads to a wide spectrum of technical safety requirements which are used to assess the reliability of production sistems rather precisely.

1 ZANESLJIVOST KOT OSNOVNI ELEMENT CELOVITEGA OBVLADOVANJA KAKOVOSTI

Temelj za sistemsko izgradnjo sistema zagotavljanja zanesljivosti proizvodnih procesov so danes že po vsem svetu uveljavljeni standardi serije ISO 9000. Zanesljivost ni samo tehnična funkcija, temveč kot nova oblika vodenja temelji na strategiji celovitega obvladovanja kakovosti.

Zanesljivost moramo načrtovati, preverjati in krmiliti, torej je v nenehnem spreminjanju in izpopolnjevanju, da bi zagotovili primeren in obvladan proces, pri čemer je nujno uvesti računalniško podporo.

Določanje kakovosti in varnosti ter zanesljivosti sistemov se ravna po zakonih, tehničnih predpisih in standardih. Zanesljivost in z njo povezana kakovost proizvodnih procesov sta zelo širok pojem, ki prehaja okvire pravnih, ekonomskih in tehničnih pravil ter vse bolj odseva politiko, filozofijo in kulturo nekega naroda.

V sistemu celovitega obvladovanja kakovosti je predvsem pomemben gospodarski uspeh podjetja, na kar zraven dejavnikov časa in stroškov močno vpliva tudi zanesljivost proizvodnih procesov. Na sliki 1 vidimo, da se zanesljivost, ki pomeni pravzaprav kakovost, ohranjeno v določenem času, kaže v zunanji in notranji zanesljivosti [5].

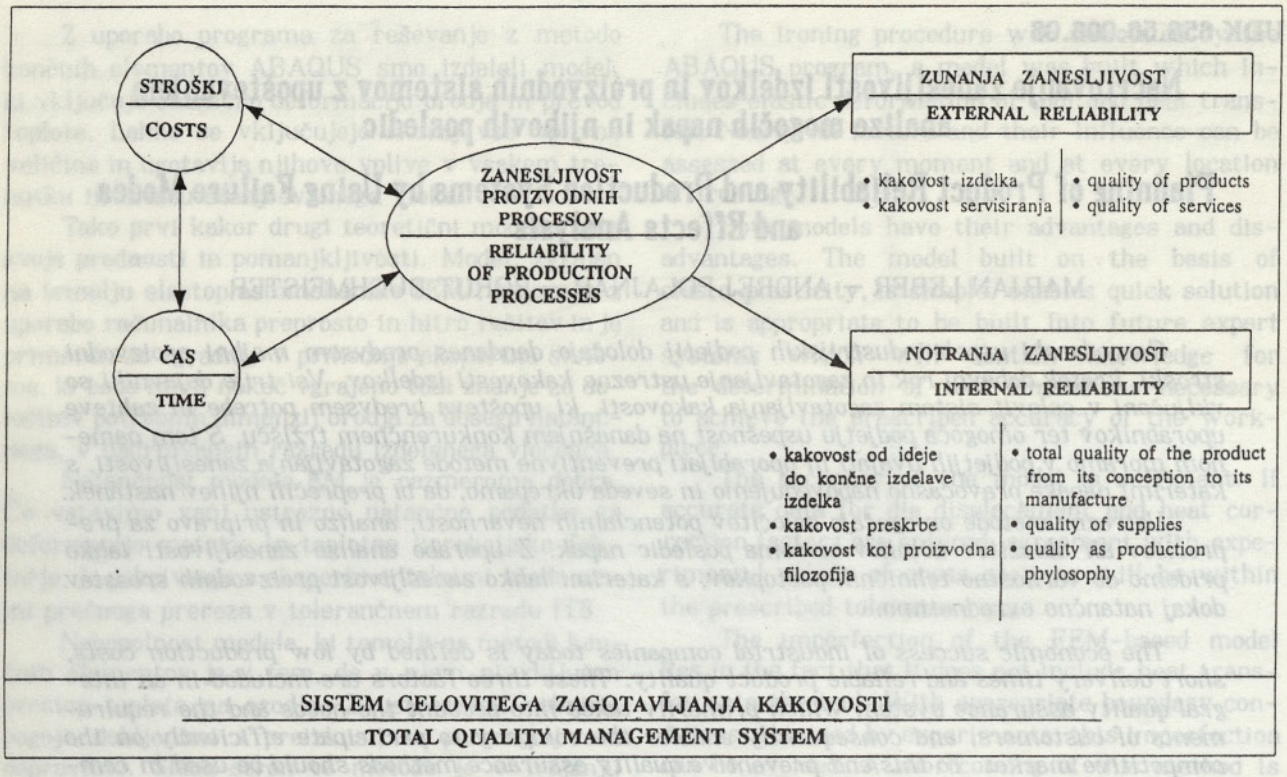
1 RELIABILITY AS THE BASIC ELEMENT OF TOTAL QUALITY MANAGEMENT

A systemic approach to building the quality assurance systems of production is nowadays based on ISO 9000 standards series, which are widely used in the world. Reliability assurance is both an engineering and management function and is, as such, based on the strategy of total quality management.

Reliability must be planned, controlled and managed. It is being continuously changed and completed, with the aim of establishing an efficient and controlled process supported by a computer.

The level of safety and reliability of production systems is determined by laws, engineering rules and standards. Reliability, and consequently the quality of production processes, are a comprehensive term which goes beyond legal, economic and engineering regulations, and increasingly reflects the policy, philosophy and culture of a nation.

The goal of a Total Quality Management system (TQM) is the overall economic success of a company, which depends not only on time and cost factors but also strongly on the reliability of production processes. Figure 1 shows that reliability, which is actually quality in a certain time, is twofold: external and internal reliability [5].



Sl. 1. *Vloga zanesljivosti v sistemu obvladovanja kakovosti*
Fig. 1. *Role of reliability in a quality management system*

Vsebina zanesljivosti ni samo v tehničnem razvoju, ampak še bolj v vsebini odnosov med ljudmi, kar se kaže pri stalnem izboljševanju delovne kakovosti posameznikov in predvsem delovne skupine zaposlenih. To pa je tudi težišče sistema celovitega obvladovanja kakovosti. Človek je in vedno ostaja osnovni nosilec ustvarjanja kakovosti ter neposredno deluje na vse načrtovane in sistemske ukrepe za dosego zaupanja in za dejansko izpolnitev kakovostnih zahtev. Raziskave v naših podjetjih so pokazale, da je človek poglavitni vir večine vzrokov napak, ki se kažejo na izdelku.

2 ANALIZA MOGOČIH NAPAK IN NJIHOVIH POSLEDIC

Uvajanje TQM je proces, ki potrebuje aktivno podporo vseh zaposlenih, z različnimi metodami pa obravnava vse faze od zamisli izdelka do prodaje. Kot ena izmed uporabnih metod se v praksi pogosto pojavlja »Analiza mogočih napak in njihovih posledic« (FMEA) [2], [3].

V laboratoriju za načrtovanje proizvodnih sistemov na TF v Mariboru smo razvili k metodi FMEA računalniški program, ki omogoča hitro in učinkovito izvedbo analize, obenem pa sprotno spreminjanje podatkov in rezultatov kakor tudi sporočanje teh preostalim službam v podjetju.

The notion of reliability is not narrowed only to engineering development, but embraces human relations which bring about steady improvements in the working efficiency of individuals and working teams. This is precisely the goal of a Total Quality Management system. Person remains the basic creator of quality and directly influences all planned and systems measures for winning customers' confidence and satisfying quality requirements. Investigations in our companies have shown that the majority of causes of failure are provoked by people, what inevitably leads to defective products.

2 FAILURE MODES AND EFFECTS ANALYSIS

The introduction of the TQM is a process which needs the active support of all employees. It covers, by different methods, all phases from the conception of a product to its sale. One of the efficiency methods frequently used in practice is Failure Modes and Effects Analysis (FMEA) [2, 3].

The FMEA method was supplemented in the Laboratory for production Systems Planning at the Faculty of Engineering in Maribor by a computer program which allows a quick and efficient analysis performance and concurrent updating of data and results, as well as their transfer to other departments in a company.

Metoda FMEA omogoča določitev mogočih nevarnosti, s tem pa tudi analizo in pripravo za preprečitev ali ublažitev učinkov oziroma posledic napak na končnem izdelku. Izboljšanje kakovosti z zaščito proti nastanku napak je primerna pot k izpolnitvi zahtevanih ciljev kakovosti nekega sistema kakor tudi rešitev vrste problemov kroga kakovosti – stroškov – produktivnosti. Stroški za dosego ustrezne kakovosti so vsekakor najnižji, če analize in ukrepe izvedemo v fazi razvoja izdelka in znatno porastejo, če napake odkrivamo in odpravljamo v končni fazi uporabe izdelka. Seveda je pri tem treba misliti tudi na ugled podjetja, ki se v slednjem primeru znatno zmanjša.

Analize FMEA lahko izvajamo v začetni fazi pri uvajanju novega izdelka ali pa tudi med izdelavo že vpeljanih izdelkov. Pri tem ločimo konstrukcijsko in procesno (tehnološko) FMEA, ki se medsebojno vedno dopolnjujeta.

Vsaka analiza FMEA terja temeljito pripravljalno delo, ki naj za vsak izdelek ali proces obravnava [1]:

1) *funkcijo izdelka*, ki obsega:
– konstrukcijski načrt, pregled montaže,
– funkcijske opise,
– sistemske specifikacije,
– delovodnik,
– podatke o znanih pomanjkljivostih (statistični nadzor kakovosti);
2) *varnostne predpise*;
3) *dokumentirane izkušnje*:
– poročila o preizkusih;
4) *proizvodni proces*:
– načrt poteka procesa,
– načrt nadzora izdelka,
– načrt nadzora sredstev;
5) *seznam mogočih problemov pri uvajanju*:
– novih izdelkov,
– novih materialov in postopkov,
– novih tehnologij;
6) *kataloge*:
– potencialnih vrst, posledic in vzrokov napak,
– mogočih nadzornih ukrepov,
– ocenitvenih meril za nastanek, pomen in odkritje vzrokov napak;
7) *sprotno sporočanje informacij drugim službam v podjetju.*

3 IZVEDBA ANALIZE Z RAČUNALNIŠKO PODPORO

Računalniški program omogoča izvedbo analiz z uporabo katalogov mogočih napak, posledic, vzrokov, ukrepov ter ocenitvenih meril, ki si jih uporabnik programa lahko sam izdela ali sproti dopolnjuje.

The FMEA method allows the determination of potential risks, their analysis and the preparation of measures to prevent or attenuate the effects of failures on final products. To improve quality by preventing failures is an appropriate way to achieve the quality goals of a system and to solve problems arising from the quality-costs--productivity circle. Costs for the achievement of appropriate quality are lowest if analyses and measures are performed in the development phase, but increase rapidly if failures are detected and repaired when the product should be put into use. It goes without saying that in the latter case the image of the company in also damaged.

The FMEA can be performed during the starting phase of product development, or during product manufacture itself. On this basis we distinguish design and process or technological FMEA which complement each other.

Every Failure Modes and Effect Analysis demands thorough preparatory work which should include below stated data for a product or process [1]:

1) *product function including*:
– design plan, assembly plan,
– functional descriptions,
– systems specifications,
– working plan,
– data on known failures (statistical quality control);
2) *safety regulations*;
3) *documented experience*:
– testing reports;
4) *manufacturing process*:
– plan of the process cycle,
– plan of product control,
– plan of production facilities control;
5) *list of possible problems in introducing*:
– new products,
– new materials and processes,
– new technologies;
6) *catalogues*:
– of potential failure types, causes and consequences,
– of possible control measures,
– of estimation criteria for failure occurrence and effects, and detection of their causes;
7) *updating and transferring information to other company departments.*

3 ELABORATION OF COMPUTER-AIDED ANALYSIS

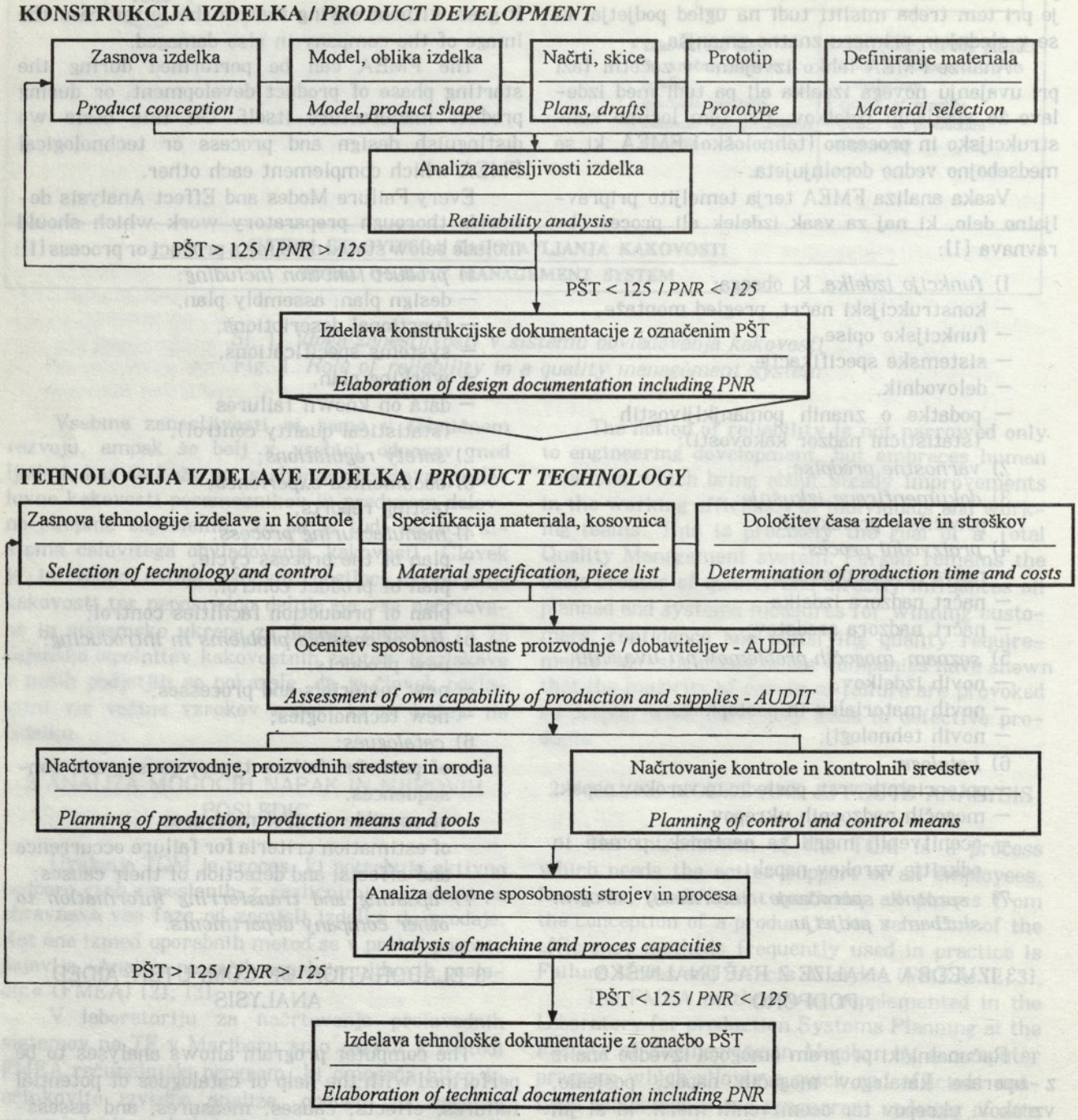
The computer program allows analyses to be performed with the help of catalogues of potential failures, effects, causes, measures, and assessment criteria which can be completed in each case by the user himself.

Postopek analize mogočih napak in njihovih posledic (FMEA) izvedemo v fazi načrtovanja izdelka (konstrukcijska FMEA) oziroma tehnologije izdelave izdelka (procesna FMEA). Z narejenimi katalogi mogočih napak, vzrokov, posledic, ukrepov in ocenitvenih meril ponuja postopek vrsto bistvenih prednosti, ki jih moramo pri izdelavi in uporabi kar se da najbolj izkoristiti (sl. 2).

Prednostno število tveganja (PŠT) izračunamo z množenjem ocenitvenih točk za verjetnost nastanka napake (N), pomen oziroma vpliv napake

Failure Modes and Effects Analysis (FMEA) is used in designing the product (design FMEA) and in the product technology (process FMEA). Catalogues of potential failures, their causes and consequences, preventive measures and evaluating criteria have been elaborated. They offer important advantages which must be used as much as possible in production and after-sales (Fig. 2).

The priority number of risks (PNR) is calculated by multiplying the assessment points obtained for the probability of failure occurrence (N),



Sl. 2. *Potek načrtovanja izdelka in vključitev analize FMEA*
Fig. 2. *Product planning with inclusion of FMEA*

(P) ter verjetnost odkritja napake (O). Velikost PŠT je merilo, ki poda prednost, s katero pripravimo ukrepe za odpravo različnih vzrokov napak — tako moramo prednostno obdelati vzroke z največjim PŠT in z največjo verjetnostjo nastanka napake.

Predvidene ukrepe iz FMEA moramo uresničiti, rezultat pa je dosežena vrednost prednostnega števila tveganja (PŠT), ki ga upoštevamo pri izvajanju ukrepov [5]:

$1 \leq$ PŠT ≤ 125: tveganja ni, korekcija ni potrebna;

$125 <$ PŠT ≤ 200: srednja vrednost, tveganje običajno sprejmemo, korekcija s preprostimi ukrepi;

$200 <$ PŠT ≤ 1000: korekcijski ukrepi so nujno potrebni.

Pri razvoju novega izdelka obravnava FMEA najprej razvoj oziroma konstrukcijo izdelka ter določi vrednosti PŠT. Dokumentacijo z označenimi vrednostmi zatem posreduje v načrtovanje tehnologije izdelave izdelka, ki določi vrednosti PŠT za posamezne operacije, proizvodna sredstva in orodja ter nadzorna sredstva [4] (sl. 2).

Računalniško podprt sistem FMEA omogoča sporočanje vrednosti PŠT v banko tehnoloških podatkov, kjer je na vpogled drugim službam v podjetju in pomaga s tem tudi pri pomembnih poslovnih odločitvah. PŠT tako na nek način kvalificira raven kakovosti izdelka, polizdelka ali dela in narekuje uvedbo novih postopkov, tehnologij ali opreme v proizvodnjo (sl. 3).

4 SKLEP

Proizvodnja se nagiba k vedno bolj obvladovanim in učinkovitim procesom, pri doslednem upoštevanju omenjene strategije (sistem FMEA) stroški napak in nadzora niso več nujno obravnavani. Pri tem so nekatera najpomembnejša merila zanesljive proizvodnje:

— zgraditi sistem TQM,

— izdelati priročnik o zagotavljanju kakovosti in zanesljivosti,

— zagotoviti skupno delo s projektivo (razvojem),

— definirati cilje zanesljivosti v proizvodnji,

— porazdeliti cilje na elemente procesa,

— vpeljati analize kakovosti in zanesljivosti (FMEA),

— zagotoviti tekoče ocenjevanje dobaviteljev,

— uvesti metode statistične regulacije procesa (SPC) in izvajati analize zmožnosti procesa,

— redno izvajati interne avdite sistema in postopkov po priročniku o zagotavljanju kakovosti,

— vzpodbuditi sodelavce,

— izboljšati CAQ.

failure effects (P), and the probability of failure detection (O). The obtained number shows the priority for preparing measures for eliminating various failure causes. The causes showing the highest PNR, i.e. the highest probability of failure occurrence, should be treated first.

The obtained value of the priority number of risks (PNR) should be taken into account when applying correctional measures [5]:

$1 \leq$ PNR ≤ 125: no risk, correction is not necessary,

$125 <$ PNR ≤ 200: medium risk value, risk is usually accepted, correction with simple measures,

$200 <$ PNR ≤ 1000: correctional measures are indispensable.

In developing a new product, the FMEA first processes the product design or development, and determines the values of PNR. Engineering data with determined PNR values are transferred to product technology, where PNR values are determined for individual operations, production resources and tools, and control means [4] (Fig. 2).

The computer-aided FMEA system allows the transfer of the PNR values into the technological data bank, which provides information for other company departments and gives an important orientation in business decisions. The PNR determines, in a way, the quality level of products, intermediate products and working process, and points to the necessity of introducing new processes, technologies and utilities in production (Fig. 3).

4 CONCLUSION

There is an increasing tendency in industry towards establishing manageable and efficient production processes. By constantly considering the FMEA strategy, the costs of failures and control no longer represent an outstanding financial item. Below are stated some of the most important critera for reliable production:

— build the TQM system,

— elaborate a quality assurance and reliability manual,

— assure cooperation with the research and development department,

— determine reliability goals of production,

— divide goals among different process elements,

— introduce quality and reliability analyses (FMEA),

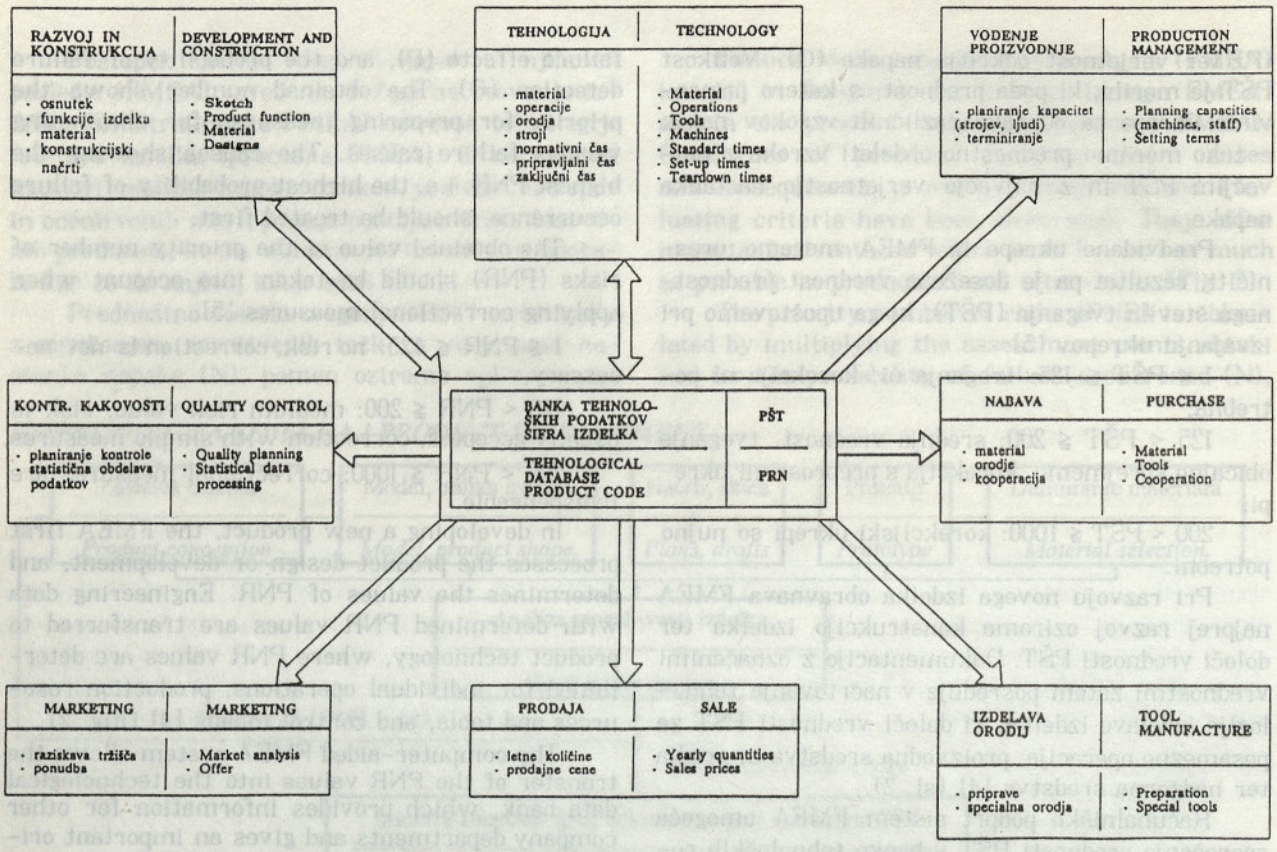
— assure the continuous evaluation of suppliers,

— introduce statistical process control and perform process reliability analyses,

— regularly perform internal audits of the system and processes according to the quality assurance manual,

— motivate workers,

— improve CAQ.



Sl. 3. *Sprotno vnašanje in sporočanje PŠT v dokumentacijo nekaterih služb v podjetju*
Fig. 3. *Presence of PNR in the documentation of some company departments*

Zagotavljanje kakovosti je celosten sistem potrebnih dejavnosti v celotnem krogu poslovanja, pri tem pa lahko trdimo, da je v sistemu celotnega obvladovanja kakovosti FMEA ena od pomembnejših metod, ki vodijo k postavitvi proizvodnega sistema z veliko zanesljivostjo.

Quality assurance is a complex system of activities which are indispensable in the complete production cycle. It can be said with certainty that in the system of Total Quality Management, the FMEA is an important method of helping to build highly reliable production systems.

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Prejeto: 23.8.1994
Received:

Sprejeto: 21.12.1994
Accepted: