CRITERIA FOR STARTEGIC EVALUATION OF RFID

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Summary: The problem of technology management is presented on example of Radio Frequency Identification. Research questions were formulated and methodology for assessment of RFID was presented. Paper is focused on strategic aspects of assessment of RFID technology. Therefore, application of portfolio method was proposed. Original set of questions for evaluation criteria was proposed and tailored to support questions related to strategic aspects of RFID application in a manufacturing company.

Keywords: RFID, technology management, portfolio method, Pfeiffer matrix

1. Radio Frequency Identification

Radio Frequency Identification (RFID) is a technology that is widely discussed and applied all over the world to support and automate logistics operations. The term RFID is used in this paper in a wide context. Every time when radio frequencies (RF) are used to identify and/or locate tagged object, author uses the term "RFID".

Basically there are hardware components and software components necessary to implement RFID solution. Hardware components are:

- elements used to tag object (RFID tags, labels, inlays),
- elements used to identify tagged objects (readers, antennas).

Unique identifier is encoded in RFID tag. Readers and antennas are used to read identifier from RFID tag. Software components of RFID solution need to cover following areas:

- management, control and maintenance of hardware components,
- data collection and filtering and grouping reads into transactions (logic messages later passed to back-end systems),
- integration and data exchange with enterprise back-end systems (such as ERP or WMS).

There is rich literature on detailed description of physics, standards related to radio waves and communication protocols, and applications of RFID [1-4]. RFID is dynamically developing and innovative, especially considering economy of Poland [5-6].

RFID offers applications that are not limited to predefined use cases and it is not only next, faster, more efficient autoidentification technology. RFID is not just better and faster barcodes. Some call it radio barcodes, what is true only to some extent. Kevin Ashton, a co-founder of the Auto-ID Center at Massachusetts Institute of Technology said: "Calling RFID a radio bar code is like calling a car a motorized horse". RFID offers new ways of execution of processes and following that it enables dramatic changes in business processes. Processes could be performed in a way previously impossible due to technology limitations. Numerous authors reported on details of RFID deployments and benefits achieved in many areas e.g. production logistics [7], warehousing [8], external supply chains [9]. At the same time authors reported difficulties in return on investment calculations and high costs of RFID implementation. The cost obstacles, which companies face with, are mostly related to costs of hardware, especially tags, if they cannot be used in

a closed loop. All considerations lead to the conclusion, that RFID implementation needs to be preceded by detailed analysis, what is typical for every innovative technology and RFID is example of such technology.

2. Assessment of RFID Technology

Analysis before implementation of RFID should focus on determination of the best possible application area, in terms of potential benefits, costs and probability of success. There should be found method to evaluate potential RFID-based improvements, to choose processes for improvement or reengineering. RFID application in manufacturing company brings several problems to analyze, discuss and solve. Problems and steps to be taken in relation to RFID implementation could be divided into few groups:

- initial decision making: choice and justification of RFID application area,
- design of RFID-supported business processes: design of objects' flow and points of identification, design of data flow,
- design of technical aspects of RFID system,
- design of integration aspects of RFID system, existing systems and other systems being implemented,
- proof of technology, tests and pilot implementation,
- roll-out of RFID solution,
- maintenance and continuous improvement of RFID solution.

Table 1 shows list of selected papers on design, implementation and evaluation of RFID solutions for logistics processes. There were no papers found that treat about strategic decisions indicating: if RFID should be considered, which and how processes should be improved and what will be the expected effect of changes.

Tab. 1. Selected papers on design, implementation and evaluation of RFID solutions for logistics processes

Ref.	Subject
[10]	Design of business processes for supply chain using RFID - support for implementation of supply chain management information system
[11]	Design and evaluation RFID system, SCOR-based integration of infrastructure with manufacturing system
[12]	Design of sophisticated and innovative RFID solutions
[13]	Design of RFID systems as IT innovations - based on general framework for "mindful IT innovation"
[14]	Analysis of benefits and barriers of RFID implementation based on literature review and questionnaire surveys
[15]	Justification of RFID implementation - very high generalization level
[16]	Evaluation of RFID impact on processes based on authors reference model of processes and benefits
[17-19]	Evaluation of RFID implementation benefits in supply chain of selected market and branch
[20-21]	Evaluation of RFID implementation benefits in supply chain - case study
[9]	Evaluation of RFID implementation benefits in supply chain - literature review of case studies (ex post evaluation) and methods for justification (ex ante)
[22]	Evaluation of RFID benefits based on simulation model

[23]	Evaluation of RFID benefits based on analytical models
[24]	Evaluation of RFID benefits based on literature review, case studies and critical success factors
[25]	Evaluation of RFID implementation based on simulation
[26]	Evaluation of RFID potential impact based on SCOR
[27]	Evaluation of RFID implementation financial effectiveness

Source: own

Listed paper (see tab. 1) treat about main categories of topics:

- evaluation in terms of characteristics of specific economies, branches and markets.
- evaluation of specific solutions based on case study,
- classification of benefits in different application areas (especially in supply chains) and relations between qualitative benefits and measurable factors,

All the authors [9-27] concluded that RFID is promising technology that eliminates numerous dysfunctions of communication processes in supply chains and is implemented successfully for logistics processes in many branches. At the same time they emphasized the need of detailed pre-implementation analysis and calculations of investment profitability.

Starting point for design of ART were papers [26-27], that treated about preliminary evaluations of RFID implementation, but were limited and lack of:

- indication which processes should be improved,
- emphasis on manufacturing processes,
- business process modeling and reengineering perspective,
- answer how to choose process for improvement (only ex post evaluation of implementation [27]),
- answer how to transpose from strategic to tactical level.

Literature lacks of research and synthetic, factory-level methods to solve problems related to design of RFID solutions on consecutive levels of strategy, tactics, operations and evaluation. 4-steps ART (Assessment of RFID Technology) method to analyze RFID potential applications in logistics processes of manufacturing company was designed.

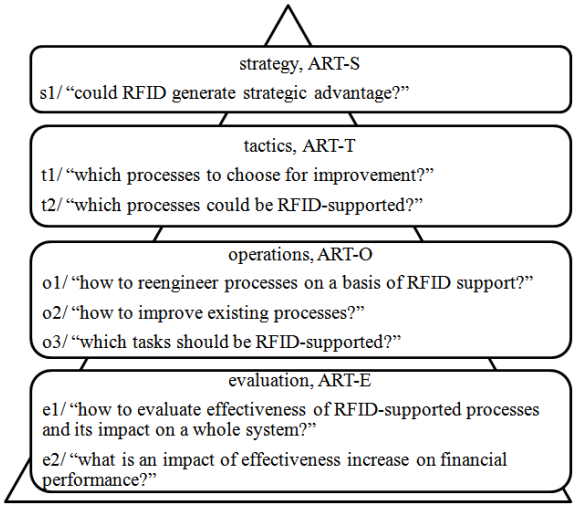

Fig. 1. Assessment of RFID Technology – research structure

Source: own

Details of strategic module of ART (ART-S) were published in [28]. Details of tactic module of ART (ART-T) were presented in [29]. More details on holistic approach proposed in ART method can be found in [30].

3. Strategic assessment of RFID

3.1. Technology management

The word „technology" comes from two Greek words:
- *techne* – art, skill, craft,
- *logos* – science, a principle of order and knowledge as defined by Heraclitus [31].

Encyclopædia Britannica [32] defines technology as "the application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment".

Technology in technical sciences means entire knowledge related to manufacturing techniques of a specified product (physical good or service) or achievement of defined effects in industry or services.

Each technology related to the specified good or service requires incurring costs of development (acquisition), implementation and integration, and first of all exploitation, related with materials, energy, human work etc. consumed per unit of product. Therefore, technologies have substantial impact on manufacturing costs, efficiency, productivity, quality, flexibility and other. Technologies determine possibility to manufacture product and to satisfy many crucial customer needs (like functional features). They are important resources that often have critical impact on competitiveness of enterprises. Therefore, technologies are treated as strategic resources of companies and enabler of achievement and preservation of strategic advantage, new ways of acting, increase of flexibility, and other.

There are many possible ways to acquire technology, including internal (own R&D) and external e.g. customers, partners, suppliers, competitors, universities, institutes, fairs, conferences, publications, Internet. The importance of a technology implies decisions on how the technology should be acquired. [33]. RFID is an example of New technology (technological innovation). Technology itself is known since many years. During II World War Royal Air Force had been using IFF (Identification friend or Foe) transponders to distinguished between own and hostile machines. Lew Termen, Russian inventor, designer listening device („The Thing") that is considered a predecessor of RFID [34]. Fast development, practical and business applications of RFID took place in 70's-80's. nowadays, RFID has entered diffusion phase (wide adoption) of its lifecycle. It was possible, because of miniaturization, decrease of costs, and increase of functional features. Numerous applications are known all over the world. Key role are playing big organization (e.g. Wal-Mart, US Department of Defense) that has mandated their partners (mainly suppliers) to implement RFID tagging. RFID is not just new technology itself, but more important it is stimulating radical changes of business processes, mainly related to logistics. There are many pros for RFID application:
- improvement of materials' flow,
- decrease of logistics' costs,
- decrease of lead times,
- decrease of errors in identification,
- enabling new ways of execution of logistics processes and related management processes, and other.

Nevertheless, there are many questions and doubts to be answered before implementation:
- purposefulness and justification of implementation,
- required financial resources,
- technical and organizational skills and competencies,

– evaluation of improvement potential,
– selection of processes to be RFID-supported, and other.

It is worth noting, that answers should be at least outlined before RFID system design and implementation starts.

There exists a broad literature on methods of strategic technology management. [35-37]. Substantial role among them are playing model of strategic analysis, which effected in 60's-70's from two reasons [38]:

– need of development of terminology foundations and proper tools to rationalize strategic decisions,
– need of method for comparison, according to unified criteria, of different areas of a company's activities and managing portfolio of those areas.

For the purpose of ART the most important among those methods are models of portfolio analysis that utilize so-called strategic matrices. Specific example is technology portfolio matrix. Fig. 2 depicts example of technology portfolio management method designed by consulting company A.D.Little.

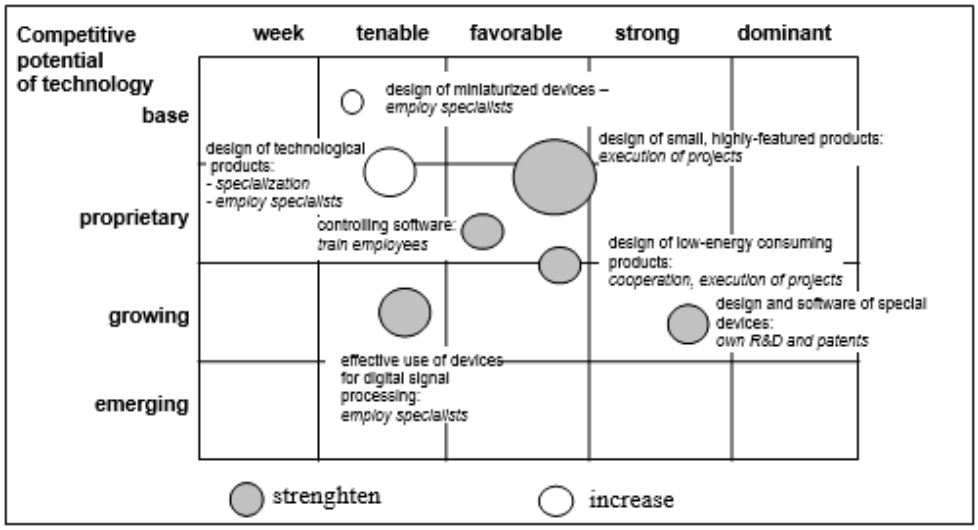

Fig. 2. Example of ADL technology portfolio
Source: translate from [33]

Depending on assumed goals and evaluation criteria, it is possible to choose from many strategic technology portfolio matrices. Phaal [37] mentioned over 850 known technology portfolio matrices. Therefore, it is substantial to answer questions: how to choose a method?, how to evaluate its usefulness and quality of results?, how to Apple chosen method in practice?, how to integrate chosen method with other tools, processes and management systems?. Next chapter sub-chapters are general description of Pfeifer portfolio [39] (ch. 3.2) and some aspects of its application for strategic evaluation of RFID (ch. 3.3).

3.2. Pfeiffer matrix

The question "s1" of ART (see fig. 1) is possible to be answered by application of methods of strategic technology management i.e. technology audit and portfolio methods. Application of one of portfolio management method widely used for technology management i.e. Pfeiffer matrix [39] was proposed and executed. Pfeiffer matrix was used for strategic evaluation and strategic justification of RFID implementation. It is useful for assessment of new technologies [39] and RFID was new technology in analyzed case.

Two main attributes of technology are evaluated in Pfeiffer matrix: technology attractiveness and resources' strength. Hierarchy of evaluated attributes is presented on fig. 3. Scale for evaluation of both main attributes is 0 to 1 per analogy to the term of efficiency. Evaluation of technology attractiveness (ETA) and resources' strength (ERS) factors are defined as real numbers. Strategic decision on purposefulness of RFID implementation (if it is rational and strategically justified) is based on ETA and ERS values (see tab. 2 and fig. 3).

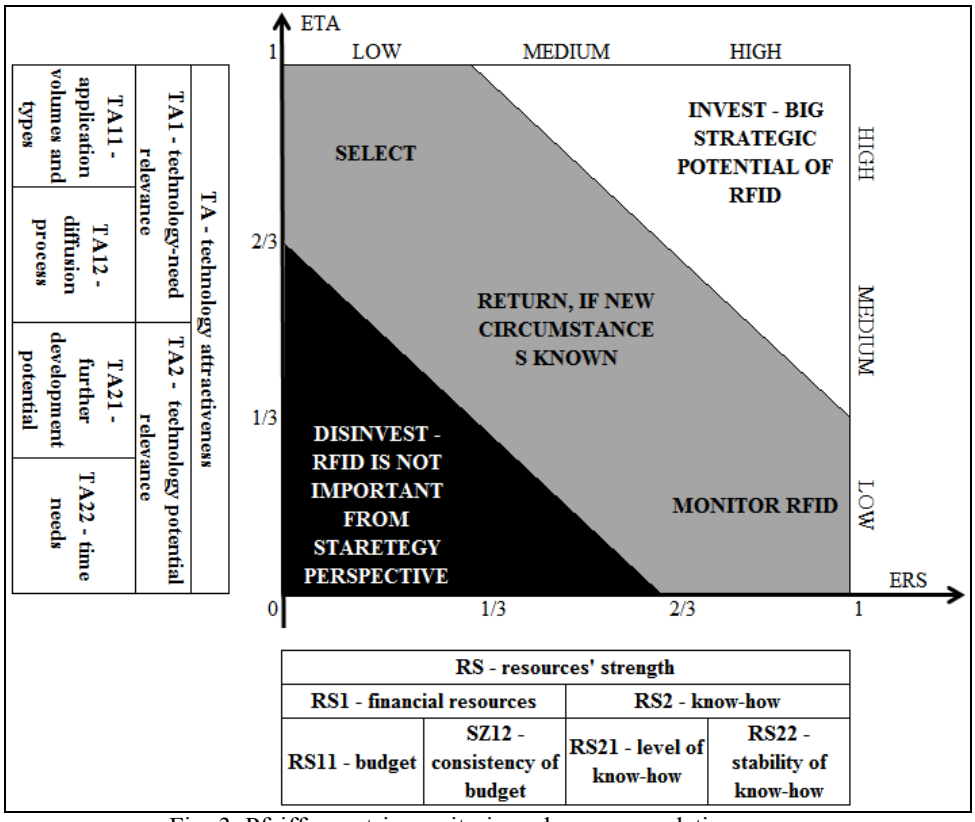

Fig. 3. Pfeiffer matrix – criteria and recommendations
Source: own based on [33,39]

Tab. 2. Strategic recommendations for RFID based on Pfeiffer matrix

Condition	Recommendation
$OAT \geq -OSZ + 1\frac{1}{3}$	**invest** in further analysis of RFID implementation in logistics of a company
$-OSZ + \frac{2}{3} \leq OAT \leq -OSZ + 1\frac{1}{3}$	**monitor** RFID, return and repeat analysis if new circumstances are known
$OAT \leq -OSZ + \frac{2}{3}$	RFID **is not important** from the perspective of a company's strategy

Source: own

All 8 lowest-level criteria (see fig. 3) are evaluated and then aggregated to determine ETA and ERS values. ETA and ERS values determine position of RFID in Pfeifer matrix and consecutively strategic recommendation for RFID (see tab. 2 and fig. 3) is given.

3.3. Questionnaire for assessment criteria

Detailed questionnaire containing 57 questions was prepared. Questions are related to all evaluation criteria and they are guidelines for experts who assign their marks to criteria. Answers for questions are justification of mark assigned to criterion. Questionnaire was designed taking into account specifics of supply chain of a manufacturing company. Questions are grouped and presented in tab. 3-10.

Tab. 3. Question for criterion TA_{11} – applications' volumes and types

No.	Questions
1	Do competitors or companies from related (close) branches use RFID? What is the trend? What are lessons learnt?
2	Do other companies from capital group use RFID?
3	Will RFID application open new markets or effect in increase of share in present markets?
4	What are the most common areas of RFID applications and are those areas critical for the company?
5	Will RFID application in supply chain generate strategic advantage? What could be the advantage?
…	…….

Source: own

Tab. 4. Question for criterion TA_{12} – diffusion process

	Do customers / suppliers / partners / subcontractors / end user / stakeholders:
1	– participate in GS1 network?
2	– expect integration and automation of information flow in supply chain?
3	– use RFID and if yes, what is the scope of application?
4	– analyze implementation (or already are using) of autoidentification technologies and if yes, what is the scope of analysis?
5	– push RFID implementation or communicate future mandating RFID implementation and if yes, what is the scope?
6	Could RFID implementation lead to benefits of further commercialization of solution, sales of new goods/services or current product with RFID feature?
…	……

Source: own

Tab. 5. Question for criterion TA_{21} – further development potential

1	What are competing technologies?
2	What other technologies are used by competitors / suppliers / customers / subcontractors / stakeholders?
3	Could company solve crucial problems and achieve comparable results and benefits applying other technologies and/or organizational solutions?
…	…….

Source: own

Tab. 6. Question for criterion TA_{22} – time needs

1	What is the potential and need for acceleration of logistics processes? Is it crucial for the company?
2	What is the advantage of RFID over other technologies in terms of potential acceleration of processes' execution?
3	Is it possible to eliminate identification mistakes in logistics processes? Are those mistakes substantial? What is the scale and level of mistakes?
4	What is RFID read rate in environment similar to potential application areas for the analyzed company? Are there known fail or success stories?
5	What is RFID efficiency comparing to other technologies and solutions?
6	What are risks related to incorrect operation of RFRID system? Is there a risk of lost, interception, unauthorized change of data? Whether this can be prevented?
7	Are there possible backup solutions, if RFID breaks down?
8	What are other pros and cons of RFID in terms of logistics processes of the company?
…	…….

Source: own

Tab. 7. Question for criterion RS_{11} – budget

1	What is estimated unit cost of additional direct materials? How is it related to the value of goods to be potentially tagged?
2	Is closed-loop application possible?
3	What is estimated investment level? What part of income is it?
4	What would be the cost of integration with existing systems (e.g. ERP, WMS)?
5	What would be the level of operating costs of RFID application? (e.g. costs of open-loop tags or replenishment of closed-loop tags)
…	…….

Source: own

Tab. 8. Question for criterion RS_{12} – consistency of budget

1	Is there a budget allocated for RFID?
2	Is there a budget allocated to investments in other technologies?
3	Is there a budget allocated to investments in logistics in general?
4	What are possible sources of financing?
5	Is lease agreement or subscription agreement possible?
6	What is expected structure of cash-flow? When first benefits and costs are expected?
…	…….

Source: own

Set of questions is open list and it is possible to modify it according to needs of particular company or preferences of expert/analyst/manager. Presented set is a guidebook for experts responsible for strategic evaluation of RFID application in supply chain of a

Tab. 9. Question for criterion RS_{21} – level of know-how

	What are employees' competences and experiences related to:
1	– RFID physics and implementations?
2	– physics of competing technologies e.g. barcodes?
3	– integration of automatics and other hardware?
4	– integration of competing technologies with other technologies, IT systems, etc.?
5	– GS1 standards?
6	– knowledge of RFID applications?
7	– knowledge of applications of complementary technologies?
8	– knowledge of applications of alternative technologies?
9	– knowledge of applications and integration of IT systems?
10	Is it possible to get or strengthen competences related to RFID and pother necessary skills through trainings, employment of qualified staff, etc.?
11	Are low and high level managers familiar with RFID? Are they positive about RFID benefits and potential?
12	What is the market (esp. domestic) of solution providers and system integrators for RFID applications?
13	What are testimonials of solution providers and system integrators? What areas are covered in testimonials?
14	Is proof of technology, technology demonstration and site reference visit possible?
15	What are solution provider and system integrator experiences? How many solutions did they deliver? Are they familiar with the branch and market, where company is operating?
16	What is the network of partners for solution provider and system integrator?
	…….

Source: own

Tab. 10. Question for criterion RS_{22} – stability of know-how

1	Is the company able to maintain RFID solution on their own?
2	Are vendors delivering complex maintenance services for RFID system? Do conditions of services meet company's requirements (e.g. repair time)?
3	What is the risk that crucial employees will confess work? How to prevent it?
4	What is the risk of termination of cooperation with solution provider and system integrator? Hot to prevent it?
5	What could the impact of termination of cooperation with vendors on project quality, time and costs? Would it cause fail of the whole project? Is it possible to replace vendors?
6	Are there risks related to complementary technologies, systems, etc.?
…	…….

Source: own

company. Experts evaluate each criterion using 5-grade linguistic scale (very low, low, medium, high, very high). Answers given for listed questions are meant to be justification of a grade assigned by expert to criterion. Linguistic scale is translated into fuzzy sets. Grades for low level criteria are aggregated and final fuzzy value of technology attractiveness and resources' strength is calculated and defuzzified. Defuzzified values of ETA and ERS are used to determine position of RFID in Pfeiffer matrix and to guide managers on strategic recommendations for RFID (see fig. 3 and tab. 2). Details of proposed linguistic scale and fuzzy numbers used for evaluation and example of ART-S application in an enterprise were published in [28].

4. Conclusion

Problems related to strategic decisions on implementation of innovative technology were discussed. Those aspects were presented on example of RFID. Assessment of RFID Technology (ART) method was outlined and questions to be answered before RFID implementation were determined.

Technology management issues were discussed and foundations of portfolio method were presented. Pfeiffer matrix was proposed to be applied for strategic assessment of RFID technology application in supply chain of a manufacturing company. Detailed guidelines for assessment of criteria listed in Pfeiffer matrix were proposed in a form of exemplary set of questions that should be answered. Set of questions was structured and questions were grouped to indicate their relation to assessed criteria.

Proposed set of questions is open list and can be modified if necessary, so experts/analysts can expand it if they discover some specific aspects related to the analyzed company.

The main goal of the paper is to serve as a guide for scientists, managers and practitioners that face problems related to strategic analysis of RFID implementation purposefulness. There are many questions to be answered, so structuring them and calculating aggregated values of technology attractiveness and resources' strength can serve as justification of decision, if RFID implementation should be discussed in details or if it is not strategically important for a company.

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